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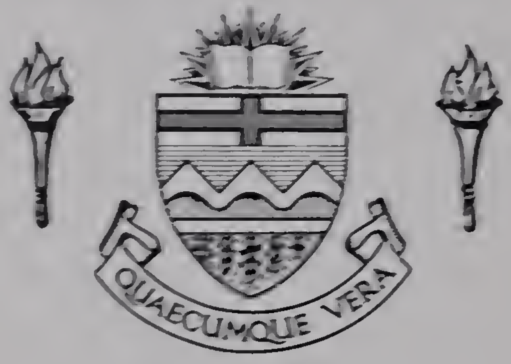

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A STUDY OF CRANIOFACIAL VERTICAL SKELETAL DISPLASIA ENCOUNTERED IN CHILDREN WITH ARRESTED ORAL HABITS

by

Ⓒ **CLARK GENTRY WOOD**

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled **A Study of Craniofacial Vertical Skeletal Dysplasia Encountered in Children with Arrested Oral Habits** submitted by **Clark G. Wood, B.Sc., D.D.S.,** in partial fulfilment of the requirements for the degree of **Master of Science.**

ABSTRACT

The purpose of the present study was to utilize vertical linear cephalometric measurements on lateral headfilms of the craniofacial complex to determine if children with a history of arrested thumbsucking habits had altered to a significant degree their basic vertical facial growth pattern during the thumbsucking interval.

Serial cephalometric radiographs were obtained from 33 persistent thumbsucking children (25 females and 8 males) at each of three observation periods: pre-treatment, post-treatment (approximately one year later), and long-term. The long-term records were obtained at a mean time of 7.95 years after the post-treatment period. Initially, the patients were grouped according to their type of growth pattern (horizontal, vertical, and horizontal-vertical) based on the cant of the SN–MP angle. Seven skeletal and four dentoalveolar linear measurements were made for each of the three different stages for each patient. Means and standard deviations were calculated for each variable. These vertical dimensions were analyzed using the age and sex-related University of Michigan mean values for comparative data for each measurement. Confidence intervals were established for each variable at the 0.95 level for the three different stages of observation and the sample study was compared to them.

There appeared to be a significant difference (0.05 level) at the pretreatment age for each of the skeletal and dentoalveolar variables except for:

(a) upper posterior face height (S–AR), and

(b) upper anterior dentoalveolar height (UM $\perp$ ANS–PNS).

All of the 33 patients who had their thumbsucking habit arrested with crib therapy, appeared to become more like the control group at the long-term observation period for all variables studied.

The total anterior face height of the thumbsucking group was found to be significantly less than that of the control group prior to the commencement of crib therapy. This was true for both the skeletal (N–ME) and dentoalveolar components (UI ⊥ ANS–PNS, LI ⊥ GO–ME). These variables did not change significantly during the one year of treatment following but fell within the range of normal compared to the control sample at the long-term observation period. This may indicate that the normal vertical growth of the anterior maxillary and mandibular dentofacial complex was possibly altered in children with persistent thumbsucking.

The total posterior face height (S–GO) showed similar results to that of the anterior face height at the three time periods. The upper posterior face height (S–AR) did not differ from that of the control group significantly at any of the three observation periods. This might possibly indicate that the upper posterior face height was not significantly affected by thumbsucking.

This study suggests that for this sample, thumbsucking may affect both the skeletal and dental structures and that the elimination of the habit allows a more normal growth pattern to occur over a prolonged period of time.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

The diagnosis and treatment of malocclusions in orthodontics depends upon a knowledge of the form and growth of the human face. There is much in the literature describing the various "theories" relating to growth and development of the dentofacial complex (Baume, 1951; Moss, 1962; Koski, 1968; Enlow, 1968; Scott, 1969). Growth in all living tissues implies that "changes" occur as a function of time. The term "growth changes" refers to any modification in the physical size, shape, or position of a structure measured per defined unit of time (Sassouni, 1971; Moss, 1964).

The effects that thumb and finger sucking have on growth and development of the dentofacial complex have long been a contentious issue (Case, 1921; Swinehart, 1938; Massler and Wood, 1949; Sillman, 1951; Bowden, 1966). With this air of uncertainty, it is not surprising that those in the dental profession cannot agree on the etiology, treatment and effects of these abnormal oral habits (Levy, 1937; Johnson, 1939; Massler and Wood, 1949; Mack, 1951; Graber, 1958a; Davidson *et al.,* 1967; Haryett *et al.*, 1970).

The association of thumb and finger sucking on malocclusions and the resulting damage to the dentition which may result is well documented in the literature (Ambler, 1904; Gardiner, 1956; Graber, 1956; Bowden, 1966; Popovich, 1966). Such things as openbites, excessive overbite and overjet, posterior cross-bite, diastemas, temporomandibular joint problems, retrusive position of the mandible, and changes in tongue and lip posture have been observed in children with these abnormal oral habits (Swinehart, 1938; Rattle *et al.,* 1953; Bowden, 1967; Gale, 1969; Levitas, 1970; Baalack and Frisk, 1971; Graber, 1972).

With the advent of cephalometrics by Broadbent (1931) and Hofrath (1931), a technique was introduced to provide standardized cephalometric radiographic films of the head and jaws. This provided the foundation for objective measurements of craniofacial changes over relatively long periods of time. Various researchers (Brodie, 1946; Bjork, 1963; Wylie, 1946) have employed these standardized cephalometric techniques to investigate the relationship of dental and skeletal components of the face and how they interact. Ortho-

dontists, in increasing numbers today, believe that a recognition of facial variation forms a large part of modern orthodontic treatment planning (Broadbent, 1937; Brodie, 1946; Coben, 1955; Sassouni, 1955; Bjork, 1963; Isaacson *et al.,* 1971). For many, this consists of measuring and describing a given patient's facial pattern in relation to some understandable and acceptable standards.

It is not surprising that most orthodontists are interested mainly in the anterioposterior malrelationships of the teeth since Edward Angle (1899), in his traditional classification of malocclusion, laid great emphasis on these common and esthetically displeasing abnormalities. With the advent of cephalometrics as a diagnostic tool, the orthodontist has, to a great extent, been able to assess the "normal" and/or "abnormal" skeletodental relationships.

Traditionally, the anteroposterior assessment of the lateral cephalometric radiograph has provided the primary criteria for making important treatment planning decisions and assessments of treatment results (Wylie, 1946; Reidel, 1952; Downs, 1948; Steiner, 1953; Sassouni, 1955). Although each researcher may have employed different landmarks and measurements, the final analyses are much the same. From these we can see that a well developed data base has been established for anteroposterior dimensions for the lateral cephalometric radiograph.

The need for an adequate vertical analysis was recognized as early as 1931 by Sir Norman Bennett. Although his classification was deficient in other respects, he did realize that vertical malrelationships may impose limitations on the treatment of anteroposterior irregularities. Little work by comparison has been done on the assessment of the vertical aspects of malocclusion. Sassouni (1955, 1969); Bjork, (1962, 1963, 1969); Wylie (1946); and Meredith *et al.* (1958) were some of the earlier investigators who examined anterior and posterior vertical facial height deviations. As our knowledge of growth and development of the craniofacial complex increases, more diagnostic emphasis has been placed on the vertical dimension and clinicians have realized that vertical malrelationships of the jaws can and do impose certain limitations on the treatment of severe malocclusions.

Biggerstaff *et al.* (1977) and others [Nahoum (1971, 1972, 1975); Opdebeeck *et al.* (1978); Opdebeeck and Bell (1978); Schendel *et al.* (1976); Subtelny and Sakuda (1964); Worms *et al.* (1971)] have in recent years concentrated more on analysis of vertical craniofacial dysplasias.

The two extremes of vertical skeletal craniofacial dysplasia are skeletal anterior open bite and deep over bite. These present a challenge to the orthodontist and investigator alike. In severe skeletal anterior open-bite cases, vertical growth predominates and this in turn causes the mandible to rotate clockwise (Subtelny, 1964; Nahoum, 1972; Worms *et al.*, 1971; Bjork, 1969; Hapak, 1964; Schudy, 1965; Opdebeeck *et al.*, 1978). The prognosis of orthodontically treated cases of this kind are poor at the best of times and surgical intervention is usually required (Nahoum, 1975). At the other extreme, skeletal deep-bites which are a result of a predominance of horizontal growth, tend to cause the mandible to rotate anti-clockwise and bring the mandible forward (Bjork, 1953, 1963, 1963; Fleming, 1961; Ricketts, 1960; Enlow, 1966). The sources for vertical dysplasias are often not easily detected but it is this information which the clinician often needs to pinpoint the major area of disharmony in the facial complex. The interplay of anterior vertical facial growth increments and posterior vertical growth increments, together with antero-posterior growth, are the responsible factors for normal occlusions as well as malocclusions.

1.1 Purpose of Study

The purpose of this study was to utilize vertical cephalometric measurements of the craniofacial complex to determine if children with a history of arrested oral habits have altered, to any significant degree, their vertical facial growth patterns. Comparisons of a long-term sample will be made to a previously studied control (Riolo *et al.*, 1974).

CHAPTER 2

REVIEW OF LITERATURE

2.0 REVIEW OF THE LITERATURE

2.1 Review of facial growth

The profile of the face has been, and always will be, one of the major concerns of the orthodontist. In the diagnosis and treatment of malocclusions, he relies a great deal upon his knowledge of the growth and development of the human face. Orthodontists have come to recognize that facial variation forms an important part of modern orthodontic treatment planning.

Growth of the skull is a complex interrelated structure rather than a series of discrete bony units (Meredith, 1951; Koski, 1964; Moore, 1977). Thus, during growth, a succession of changes occur in which the entire mosaic of the component bones is involved (Lu, 1965). Despite the identification of many growth sites, the patterns of craniofacial growth still remain controversial. Brodie (1946), in his paper entitled "Facial Patterns–A Theme on Variation", found that the effect of a marked discrepancy of an individual part of the craniofacial complex could be "cancelled out" by a deviation in the opposite direction of another part and still result in good facial harmony; similarly, the small discrepancies in the same direction might be additive and lead to marked total disharmony. Wylie (1947) in his analysis of anteroposterior dysplasia, sought to determine the variation of the internal facial morphology related to a particular profile type and came to similar conclusions as had Brodie.

Hellman (1927, 1932) was one of the first to recognize the role of growth and development in bringing about proportional changes of the face as a result of the different rates of growth in different parts. It was not until the introduction of cephalometric radiography by Broadbent (1931) and Hofrath (1931) that a standardized technique of cephalometric radiography was developed which provided a new and more precise method of studying growth of the dentofacial complex. By 1937, Broadbent had presented his first series of cephalometric diagrams in which he illustrated an orderly growth pattern of the face of a normal child. It was not long after that Brodie (1941) published a cross sectional

growth study on the human head from the third month to the eighth year. He determined from this study that the morphogenetic pattern of the head was established by the age of three months and did not change thereafter although deviations from the mean were noted in individual cases. In this study, he divided the head into several functional areas; brain case, nasal, dental, mandibular, and each was measured as a separate entity. He noted that growth of the various areas was found to be proportional and so integrated that various anatomical points travelled on a series of straight lines. After an early age, the nasal floor, the occlusal plane, and the lower border of the mandible were shown to retain stable angular relationships during growth.

In 1947, Bjork performed a radiographic comparison of the facial prognathism of 322 twelve-year-old Swedish boys with that of 281 adult males. He found that mandibular prognathism increased somewhat during growth. Since no change in the shape of the cranial base was detected, the increase in prognathism was attributed to the altering relation between the cranial base and the jaw length. He noted a slightly greater increase in mandibular jaw length as compared with that of the maxilla. He attributed this increase to the whole mandible being displaced somewhat forward in relation to the upper jaw. In a series of cephalometric studies using jaw implants, Bjork demonstrated that variations in growth do occur between facial regions and that such variations do produce rotations of the mandible in either direction (1962, 1963, 1969). He also demonstrated that the apparent constancy of downward and forward facial growth is not necessarily a result of regular or equal increments of growth. He felt that it was achieved by very unequal amounts of growth at the major growth sites accompanied by mandibular rotations and remodelling (Enlow, 1975; Gasson and Lavergne, 1977).

Lande (1952) in a serial cephalometric radiographic study of 34 patients, with an age range of 4.4 to 17.1 years, found a significant difference between the growth behavior of the mandible and maxilla in an anteroposterior direction. While the mandible tended to become more prognathic with age, the maxilla showed very little change (Bjork, 1947). Associated with the increase in mandibular prognathism was a decrease in the mandi-

bular plane to the cranial base plane. He noted that regardless of the facial type, all of the cases showed the same general tendencies in their growth behavior.

Current knowledge of postnatal human facial growth has been based largely on comparative phylogenetic correlations (Hellman, 1932; Gregory, 1929; Krogman, 1930; Todd, 1932; Bjork, 1950; Enlow, 1964, 1965), anthropometric studies (Hellman, 1935; Goldstein, 1936; Davenport, 1936) and serial cephalometric radiography (Broadbent, 1937; Brodie, 1941, 1946; Bjork, 1947; Lande, 1952). These particular studies have provided a great deal of quantitative information concerning relative growth movement, angular relationships, and rates of growth in the various facial planes. The face undergoes a progressive post-natal enlargement (Enlow, 1966) and its various proportions become markedly changed with age. The overall balanced facial profile is best achieved when a balance exists between the increments of horizontal and vertical growth.

2.2 Vertical facial growth

Orthodontists, employing cephalometric techniques have traditionally tried to identify portions of the dentofacial complex relating to malocclusions by assessing the dysplasia in an anteroposterior dimension (Downs, 1948; Reidel, 1952; Steiner, 1953). This popular classification of malocclusion (as introduced by Angle, 1899) was defined in the anteroposterior dimension only. Angle (1899) classified malrelations of the dental arches into three categories based upon shifting tooth relationships anteroposteriorly.

Creekmore (1967) stated "if it were possible to control the vertical growth of the face it would be possible to solve almost all of our orthodontic problems". Vertical growth increments in various parts of the dentofacial complex have different effects on different facial types (Schudy, 1963, 1964; Sassouni, 1964; Isaacson *et al.*, 1971).

In 1943 and 1944, Diamond observed that dental height, which he described as "those parts of the jawbones within which teeth are developing, plus the teeth in their later varying states of clinical eruption", are established primarily through growth in the vertical height of the ramus, and that excessive anterior overbite may be attributed to undue

retardation in growth-length of the ramus with consequent failure of the intermaxillary space to develop. He felt that the ramus should by increasing in its length carry the body of the mandible farther away from the upper jaw with the result that increased space for teeth was created.

Wylie (1946) used 90 untreated individuals and studied the relationship between ramus height, dental height, and overbite. He found that the total face height, lower face height, and the intermaxillary space in the molar region are significantly less in closed deep bite cases, but that there was no significant difference between the groups with respect to the height of the ramus. Wylie showed contrary to Diamond (1943, 1944) that individuals with closed bites had a decreased vertical dimension in the rest position (Brodie and Thompson, 1942; Bjork, 1947; Smeets, 1962; Atherton, 1965; Sassouni, 1964; Schudy, 1963, 1964, 1965; Ricketts, 1957, 1960; Isaacson *et al.,* 1971).

In 1952, Wylie studied 171 subjects prior to orthodontic treatment in an effort to evaluate facial dysplasia in the vertical plane. He recognized that angles in themselves serve poorly to localize and differentiate areas of dysplasia. These patients, age ranging from eleven to thirteen years, were separated into good, fair, and poor facial patterns. He measured the facial height, length of the mandibular body and ramus, gonial angle, and the vertical placement of the glenoid fossa of the temporal bone. His data revealed that subjective evaluations of poor facial patterns tended to have:

–large lower face heights,

–increased mandibular plane angles, and the

–glenoid fossa of the temporal bone was relatively high.

Meredith *et al.* (1958) studied 55 subjects longitudinally using lateral cephalograms to determine the nasal and subnasal components of facial height in children. Subjects in the study, both male and female, ranged from four to twelve years. They found that for individuals, nasal height (upper face height) in percentage of subnasal height (lower face height) may remain practically constant from age to age, or it may increase as much as fifteen percentage points (Jones and Meredith, 1966). They noted that individual differen-

ces in upper face height relative to lower face height are distributed from a minimum of 65.0% (at age four years) to a maximum of 91.6% (at age eleven years). This study challenges the work previously done by Brodie (1941, 1942, 1953) who felt that between birth and adulthood, the average percentage contribution of parts of the face to the total face height are the same regardless of age.

Schudy (1963) performed a lateral cephalometric study of 400 random sample malocclusions in an attempt to relate OM (occlusal-mandibular plane) angles to facial types. He selected from this group those that had high and low OM angles and suggested that the OM angles were excellent indicators of facial type which he referred to as prognathic and retrognathic. He further pointed out that the OM angles are significantly related to ramus growth. This angle was shown to be a measure of relative mandibular molar dento-alveolar height. He felt that it is the relationship of the ramus height to the posterior dento-alveolar height which largely determines overbite. In 1964, Schudy introduced the term facial divergence, the extremes being hypodivergent and hyperdivergent, as a more specific description of facial type. The prognathic faces were characterized by low occlusal and mandibular plane angles, square jaws, deep overbites, and short wide symphyses. The retrognathic faces in contrast had high OM angles and high mandibular plane angles, tall narrow sympheses, and open-bites.

Droel and Isaacson (1972) evaluated 62 patients with ANB angles of less than 0.5 degree or greater than 4.0 degrees. These represented approximately one standard deviation from Riedel's mean (1952). They tried to determine the relationship of the glenoid fossa position to various skeletal discrepancies. They used a number of linear and angular measurements to analyze the cephalometric radiographs. Since skeletal discrepancies in both the anteroposterior and vertical dimension are highly dependent upon the relationship of the mandible to cranium (Sassouni, 1964; Richardson, 1969; Bjork, 1963, 1969; Creekmore, 1967; Schudy, 1965; Schendel *et al.,* 1976). Droel and Isaacson felt that the position of the glenoid fossa was a good indicator of certain types of malocclusion. They noted:

–that a relative reduction in the vertical distance from the joint fossa to sella

produced an effectively short ramus and contributed to a steep mandibular plane angle.

–that a relative increase in the vertical distance from the joint fossa to sella tended to increase the length of the ramus, producing a flatter mandibular plane angle.

It is well recognized that the mandible rotates both clockwise and counterclockwise as the growth processes unfold (Wylie, 1946, 1952; Meredith *et al.,* 1958; Bjork, 1962, 1963, 1969; Johnson, 1950; Creekmore, 1967; Schudy, 1965; Richardson, 1967; Lavergne and Gasson, 1977; Isaacson *et al.,* 1971). This rotation of the mandible resulting from disharmony between vertical growth and anteroposterior or horizontal growth has important implications on orthodontic treatment.

In 1965, Schudy randomly selected 50 patients from a group of 400 malocclusions whom he had treated. These patients had been treated over a three-year period from the age of eleven to fourteen years. All of these patients were treated without extractions and were of average facial proportions. He found the relationship of facial height to depth had a high correlation when calculated on the Y-axis at SN, the Y-axis at Frankfort, and the X-Y axis (.64, .49, .78, respectively). When he correlated these axes with lower facial proportions, he found very low associations. Thus, according to Schudy, it would appear that the Y-axis and X-Y axis are not closely associated with the morphology of the lower face, whereas both the SN–MP and OM angles are. He also noted that there was a high correlation coefficient (.92) with growth of total vertical height in the molar region. This would indicate a high degree of association between vertical facial height and molar height. He felt that the degree of facial divergence had a strong affect upon the degree of rotation of the mandible (Bjork, 1963, 1969; Ricketts, 1957; Sassouni, 1964; Isaacson *et al.,* 1971; Lavergne and Gasson, 1977).

Ricketts (1970) in a serial cephalometric study on 250 patients tried to determine the influence of orthodontic treatment on facial growth and development. He studied the effects of headgear and intermaxillary elastics on rotations of the mandible. He

found that headgear therapy tended to open the X–Y axis in both the prognathic and retrognathic cases, thereby increasing the vertical facial height.

Most cephalometric analyses in the past (Downs, 1948; Reidel, 1952; Steiner, 1953), using lateral radiographs focused their attention on anteroposterior discrepancies. Cephalometric standards for vertical relationships have remained less well developed. It was not until the early 1950's that there began to be some constructive cephalometric assessment of posterior and anterior vertical facial height deviations (Wylie and Johnson, 1952; Coben, 1955; Meredith *et al.*, 1958; Sassouni, 1955; Bjork, 1961).

In recent years Biggerstaff *et al.* (1977), Schudy (1964), Creekmore (1967), Sassouni and Nanda (1964), Nahoum (1971), Droel (1972) and Isaacson *et al.* (1971) have focused their attention more on the problems associated with vertical skeletal dysplasias. Vertical skeletal malocclusions are commonly defined in terms of height of the lower portion of the face relative to the total face height in both the anterior and posterior segments (Wylie and Johnson, 1952; Coben, 1955; Schudy, 1964).

Isaacson *et al.* (1971) described in depth a number of vertical components that commonly affect vertical facial dimensions:

–The vertical position of the glenoid fossa relative to the cranium.

–The amount and direction of condylar growth of the mandible.

–The amount of vertical growth between sella-nasion and the palate.

–The amount of vertical growth between occlusal plane and the lower border of the mandible.

–The amount of maxillary dentoalveolar growth.

They noted that the relationship of the mandible relative to the cranium was dependent upon the amounts of growth of each of the previously mentioned components as well as between them. Disproportionate increments of growth caused various rotations of the mandible thereby changing the centre of rotation (Bjork, 1969; Schudy, 1965; Lavergne and Gasson, 1977).

Therefore, the balance between the various vertical growth components can

determine the anteroposterior relationships of the mandible relative to the cranium (Schudy, 1964, 1965; Bjork, 1969; Isaacson *et al.*, 1971; Droel, 1972; Lavergne and Gasson, 1977). Alterations in the various vertical growth components can therefore alter vertical and horizontal facial proportions. It is the extremes of these various growth components in the horizontal and vertical planes of space which manifest themselves in severe skeletal malocclusions.

2.3 Extremes in Vertical Growth

In assessing vertical skeletal dysplasias, both the skeletal and dental components must be distinguished in order to make an accurate evaluation of the malocclusion. Since bite depth is determined by the contact relationship of the teeth, the terms "skeletal open-bite" or "skeletal deep-bite" contain, in a sense, inherent contradictions. Through the work of Sassouni (1971), these two terms have come to be understood by orthodontists as indicating skeletal proportions which cause a built-in tendency toward open- or deep-bite dental relationships.

2.3.1 Deep bites

Deep-bites are one of the most common manifestations of vertical skeletal dysplasia associated with malocclusions. Bjork (1947), in "The Face in Profile", said that overbite is inversely proportional to the facial height. He stated that the "mechanics" of increased depth of bite are that the jaws close more intimately causing the face to appear somewhat compressed.

Sassouni and Nanda (1964) studied the dentofacial vertical proportions of open- and deep-bites and outlined a number of dental and skeletal characteristics associated with them. They reported only those factors that had been well established and noted that not all of the characteristics had to be present simultaneously. Deep-bites tended to be associated with the following:

(a) Larger freeway space (Bjork, 1947; Sarnas, 1959).

(b) Large cusp height of posterior teeth (Bonwell, 1925; Mershon, 1937; Popovich,

1955).

(c) Diminished molar dentoalveolar height (Wylie, 1946; Johnson, 1950; Prakash and Margolis, 1952; Popovich, 1955; Flemming, 1961; Schudy, 1968).

(d) More upright incisors (Steadman, 1949; Popovich, 1955; Schudy, 1968).

(e) Small total or lower anterior face height (Wylie, 1946; Bjork, 1947; Johnson, 1950; Prakash and Margolis, 1952; Smeets, 1962; Atherton, 1965; Schudy, 1968).

(f) Small gonial angle (Bushra, 1948; Johnson, 1950; Jensen and Palling, 1954; Wylie, 1957; Sassouni, 1969).

In 1925, Bonwell studied artificial teeth and noted that the overbite in the incisor region was governed by the depths of the cusps of the premolars and molars. He did find, however, that there was considerable variation among different individuals. Mershon (1937) described two types of closed bites based on clinical examination. The first type of closed bite was one in which the teeth were short and broad therefore making the distance between the maxilla and mandible unusually short. The second type was really a deep overbite which had overeruption of the lower anterior teeth and long cusps in the posterior teeth. This resulted in a lower arch with a steep curve of spee.

In 1955, Popovich using dental models and lateral cephalograms studied the factors contributing to excessive overbite in different types of occlusion. His work corroborrated many of Bonwell's (1925) observations. He noted that in the "ideal occlusion" group (17 females and 17 males) that the amount of overbite was determined largely by dental factors and that there was a strong correlation between the cusp height and overbite. In the Angle Class I malocclusion group with deep overbite, the overbite seemed to be controlled by dental factors whereas in the Angle Class II malocclusion group, skeletal factors were found to be more associated in deep overbite than dental factors. Popovich concluded from this study that dental factors alone were not responsible for deep overbite.

The dentoalveolar height is another factor which has been studied extensively in regard to deep overbites. Wylie (1946) studied 90 patients using lateral cephalometric radiograms and found a significant difference in the vertical molar dentoalveolar height

between slight-, medium-, and deep-bite groups. He found that the distance from the palatal plane to the mandibular plane through the first permanent molar was 3.5mm less in the deep overbite cases. There was no significant difference between the shallow and moderate overbite group. Similar findings have been reported by Popovich (1955), and Schudy (1968).

Schudy (1963, 1968) studied 400 patients (aged 9 to 18 years) using cephalometric radiographs combined with clinical observation and determined that the downward growth of the posterior maxillary teeth played an important role in overbite determination. He noted that a deficient growth of maxillary posterior teeth caused an increase in overbite while an excessive growth caused a decrease in overbite. Schudy felt that the vertical growth of the lower molars played a minor role in overbite determination during growth of the face. This corroborates the evidence presented previously by Wylie (1946), Bjork (1947), Prakash and Margolis (1952), Smeets (1962), Atherton (1965) that the lower face height is smaller than the average in deep overbite cases.

In 1949, Steadman stressed the relationship of the long axis of the maxillary and mandibular incisor teeth to each other as an important factor in overbite. He reported that overbite increased as the interincisal angle increased, and decreased as the interincisal angle did. Popovich (1955), Schudy (1963, 1968), Andrews (1972), Isaacson (1970), and Mills (1973) confirmed that overbite was significantly correlated with the interincisal angle. Whether or not there is a definite cause and effect relationship between the two as Schudy (1968) implied, remains to be seen.

2.3.2 Open-bites

Descriptions of open-bite differ among various authors and investigators. Because of these differences, the incidence of open-bites reported in orthodontic practices will also vary. For our purposes, open-bites will be considered as a deviation in the vertical relationship of the maxillary and mandibular arches. According to Subtelny (1964), lack of contact in the vertical direction between opposing segments constitutes an open-bite. Open

bites tend to be associated with the following:

(a) The total maxillary dental height is greater in open-bites at both the incisor and molar levels (Wylie and Johnson, 1952; Muller, 1961; Subtelny, 1964).

(b) Short ramus height (Hallman, 1931; Swinehart, 1942; Subtelny, 1964; Bjork, 1969; Isaacson *et al.*, 1971; Nahoum, 1972; Schendel *et al.*, 1976).

(c) Higher vertical placement of the glenoid fossa in the temporal bone (Wylie and Johnson, 1952; Hopkins *et al.*, 1968; Bjork, 1969; Droel, 1972).

(d) The lower anterior face height is increased in open-bites (Bjork, 1947; Prakash and Margolis, 1952; Hapak, 1964; Subtelny and Sakuda, 1964; Sassouni and Nanda, 1964; Richardson, 1969; Nahoum, 1972; Schendel *et al.*, 1976).

(e) Gonial angle is greater in open-bite cases (Wylie and Johnson, 1952; Sassouni, 1964, 1969; Bjork, 1969; Richardson, 1969; Nahoum, 1975; Schendel *et al.*, 1976).

Subtelny and Sakuda (1964) conducted a cephalometric study and studied the skeletodental relationships of 25 subjects with persistent open-bite compared with that of a group of 30 subjects with normal occlusions. All of the subjects were over 12 years of age, but no differentiation was made between the two sexes. They found that the dimensions from the nasal floor to the occlusal surface of the maxillary first permanent molar and to the incisal edge of the permanent central incisor were significantly greater in open-bite cases. In assessing the overall vertical dimension from nasion to the lower border of the symphysis of the mandible, it was found to be significantly larger in open-bite cases (Wylie, 1946; Wylie and Johnson, 1952; Prakash and Margolis, 1952; Droel and Isaacson, 1972; Nahoum, 1972; Opdebeeck *et al.*, 1978). They also found that this excessive vertical dimension of skeletal face was restricted to the lower face region (Wylie, 1946; Prakash and Margolis, 1952; Subtelny and Sakuda, 1964; Opdebeeck *et al.*, 1978).

In 1964, Sassouni and Nanda studied eight adults with skeletal open-bites and eight adults with skeletal deep-bites. These patients were derived from a longitudinal series of 250 patients (from the Child Research Council in Denver, Colorado) on whom cephalometric records had been kept from birth to adulthood. Their observations concurred

with Subtelny and Sakuda (1964) and Richardson (1969) that the total maxillary dental height was greater in persons with open-bite, at both the incisor and molar levels.

Recently, considerable emphasis has been placed by oral surgeons on severe vertical skeletal dysplasias. Studies by Schendel *et al.* (1976) and Opdebeeck *et al.* (1978) have confirmed much of the work done by Hellman (1931), Swinehart (1942), Wylie and Johnson (1952), Subtelny and Sakuda (1964), Sassouni (1964, 1969), and Richardson (1969), who found that the gonial angle in open-bite cases is much greater than in normal or deep-bite cases as well as a shorter ramus height.

In 1972, Droel and Isaacson designed a study to compare extreme variations in facial growth in order to examine the relationships between the glenoid fossa position and skeletal malocclusions. Since skeletal discrepancies in both the anteroposterior and vertical dimension are highly dependent upon the relationship of the mandible to the cranium (Downs, 1948; Reidel, 1952; Schudy, 1964, 1965; Bjork, 1969), it can be hypothesized that the position of the glenoid fossa relative to the skull are related to the various skeletal discrepancies. They examined 62 patients (31 males and 31 females) and categorized them according to mandibular plane and ANB angles. They found that a relative reduction in the vertical distance from the summit of the joint fossa to sella produced an effectively short ramus and contributed to a steep mandibular plane syndrome often associated with severe skeletal open-bites. They also noted that an increase in the vertical distance from the joint fossa summit to sella gave the net effect as if the ramus were longer, producing a flatter mandibular plane often associated with deep-bites.

Hopkins *et al.* (1968) and Bjork (1969) also reported that the position of the glenoid fossa anteroposteriorly was related to dental malocclusions. Bjork (1969) further noted that the vertical placement of the glenoid fossa was a theoretical factor in the rotation of the mandible.

On comparing the two extremes of open- and deep-bite, the difference in the lower face height seems to be the only skeletal factor which has been confirmed and authenticated by repeated investigation. The limited findings for skeletal abnormalities in

open-bite and the controversy over the importance of skeletal factors in deep overbite may be attributed to differences in age, sex, growth, and the possibility that all open-bites or deep overbites are not uniform with respect to etiologic factors.

2.4 Incidence of thumb- and finger-sucking

The incidence of thumb- and finger-sucking reported in the literature is quite varied depending on the selection of the sample. Traisman and Traisman (1958) found that 45.6% of 2,650 children examined had a history of thumbsucking. Popovich and Thompson (1973) reported that the incidence at six years of age was approximately 40% and that it gradually decreased as children got older. Anderson *et al.* (1973) reported that children in higher socioeconomic levels tended to retain thumbsucking habits longer than their counterparts from lower socioeconomic levels.

The prevalence of thumb- and pacifier-sucking children was studied in two "kibbutz" settlements and city nurseries by Zadik *et al.* (1977). Data on 333 children was collected and the variables considered were age, sex, duration of breast feeding, and family size. Differences in prevalence were found between the three groups. Among the city children, 95% had oral sucking habits while 89% and 69% of the kibbutz children had sucking habits. With the increase in age, the incidence of oral habits decreased in all groups. There was no difference found between the sexes. No association was found between the habit and the duration of breast feeding. They noted a reverse association between finger and pacifier sucking and suggested that the pacifier may be a substitute of choice for thumbsucking. The prevalence also appeared to be highest in single children.

2.5 Effects of thumb- and finger-sucking

It has been shown over the years that malocclusions associated with thumbsucking are either caused or aggravated by the habit (Swinehart, 1938; Massler and Wood, 1949; Sillman, 1951; Ruttle *et al.*, 1953; Bowden, 1966, 1967; Larson, 1972; Graber, 1972). Angle (1907) in his text, *Treatment of Malocclusions of the Teeth,* noted that thumbsucking had little effect on displacing deciduous teeth. He did however, conclude that

if the abnormal oral habits persisted into the permanent dentition, that the permanent incisors could be adversely affected. Case (1921) on the other hand felt that the deciduous teeth could very definitely be affected and that the dental arches could become significantly constricted in cases of severe thumbsucking.

In 1938 Swinehart studied 34 children who sucked their thumb or fingers and noted a variety of problems associated with their oral musculature and functional occlusion. He observed that there were both active and passive forces exerted during thumb- and finger-sucking. The kind and degree of the effect was dependent upon the method and duration of the habit. He further noticed that "pernicious" secondary habits of the tongue and lips were formed and frequently persisted after the thumbsucking had ceased. He concluded that these abnormal pressure habits were an important factor in the etiology of Class II malocclusions and that they aided in causing malocclusions by mechanically inhibiting or exaggerating the normal vertical growth of the maxilla. He did feel that there was a tendency toward self correction of the simple types of anterior open-bites upon cessation of the habit, provided that there were no secondary factors involved.

The particular influence that thumb- and finger-sucking habits have on malocclusion is dependent upon the position of the thumb or fingers, the duration, intensity, and the frequency of the habit, and the associated muscle contractions of the lips and cheeks. Massler and Wood (1949) felt that when lip and tongue function is normal, malocclusions of the deciduous dentition caused by thumbsucking usually corrected themselves after the habit had ceased, while malocclusions of the mixed or permanent teeth were usually not self-corrective. Graber (1958) described the intensity, duration and frequency of the habit as the most important factors that would ultimately contribute to the severity of any deleterious effects from sucking habits. Taft (1966) studied 35 children who had prolonged thumbsucking habits and concluded that changes to the maxilla and the dentition were not significant. However, he did conclude that mandibular posture was affected.

Sillman (1951) evaluated sixty children from birth to fourteen years of whom twenty were thumbsuckers. He concluded that malocclusions often became more severe

and that thumbsucking affected the oral structures of a child with a poor dental occlusion more than those with good occlusions.

In 1952, Klein studied some of the etiological factors associated with thumb- and finger-sucking. He noted that considerable damage occurred from the abnormal pressure habits of the thumb and fingers and that most of the damage occurred during the mixed dentition stage. He also concluded that if these pressure habits were discontinued prior to four years of age that there would be little permanent damage to the dentition. Persistence beyond age four, however, was likely to cause harmful effects.

2.6 Relationship of thumb- and finger-sucking to skeletal problems

Many investigators are agreed that thumb- and finger-sucking habits can lead to a reduced overbite and often the development of an anterior open-bite (Ruttle *et al.*, 1953; Gardiner, 1956; Graber, 1958; Baril and Moyers, 1960; Backlund, 1963; Hapak, 1964; Subtelny and Sakuda, 1964; Bowden, 1966).

Hughes (1949) agreed with Swinehart (1938) when he reported that nearly 16% of children with sucking habits developed a malocclusion so severe that it was not self-correcting and needed extensive orthodontic treatment to correct it. Ruttle *et al.* (1953) observed that thumb- and finger-sucking habits could prevent the normal eruption of the anterior teeth. In a comparative study using clinical examinations and dental models, 36 children with persistent oral habits were studied and serial records for all patients were obtained each year from age two to fifteen years. All of the patients except one commenced oral sucking habits during the first year of life. They concluded that open-bite, which was found in ten out of the 36 children with these habits, was caused primarily by thumb- and finger-sucking habits.

It was noted by Kantorowicz *et al.* (1926) that approximately 4.2% of a population of six-year-old children were reported to have open-bite malocclusion, while only 2.5% of a population of fourteen-year-old children were found to have open-bite malocclusion. On the basis of these data, almost twice as many open-bites might be anticipated

in a six-year-old population groups as would be anticipated in a fourteen-year-old population group. Thus, directly or indirectly, the age gradient is an important factor in open-bite malocclusions.

Swindler and Sassouni (1962) studied the development of an anterior open-bite in 47 rhesus monkeys with a thumbsucking habit. No cephalometric data was reported. They found that the effects of the thumbsucking on the dental occlusion was generally restricted to the maxillary anterior section. They reported that there seemed to be an elongation of the premaxillary dental arch with spacing between the maxillary anterior teeth.

In a cephalometric appraisal of open-bite cases, Hapak (1964) studied 52 untreated Caucasian patients (mean age of 12.3 years), all of which exhibited an anterior and/or lateral open-bite. He observed that the effects of the thumb habit and tongue thrust upon the axial inclinations of the upper and lower incisors was such that they produced extensive variations from the normal with resultant open-bites.

The relative frequencies of occurrence and subsequent alterations in skeletal and muscular morphologies, molar and canine relations, open-bite, and cross-bite between the ages of two and eight years were studied in 116 chidlren by Bowden in 1966. The records included a clinical orthodontic examination in addition to dental study casts which were taken during the children's fifth and eighth years. He noted that children who engaged in intense and frequent digit-sucking showed a high frequency of occurrence of bilaterally different molar relations with a tendency toward Class II canine relations, nevertheless, he felt that it was possible that this tendency toward Class II occlusion simply reflected the inherent skeletal Class II morphologic feature. He emphasized that if intense and frequent digit-sucking changed the molar and canine relations, it must have changed the molar relations before the age of two years and the canine relations after the age of five years, in view of their constancy thereafter.

In 1972, Larsson studied 320 children using dental casts and lateral cephalometric radiographs. These patients were among the 920 children forming part of an earlier incidence study (Larsson, 1971). A comparison was made between 116 children with a per-

sistent finger-sucking habit, 54 children with a dummy-sucking habit up to more than four years of age, 50 children who had been weaned of their dummy-sucking habit between two and four years of age, and 100 children without earlier sucking habits. The comparison related to eight skeletal and nineteen dental variables. Twelve variables were recorded by measurements on a plaster cast, the other fifteen by measurements on lateral cephalometric radiographs. He noted a number of significant differences between the children in the finger-sucking group and in the control group:

(a) The maxillary dental arch is prolonged in the finger-suckers.

(b) The overjet is increased and the overbite reduced in the finger-suckers.

(c) The perpendicular distance from the edge of the maxillary incisors to a line from nasion to gnathion is increased in the finger-suckers.

(d) The inclination of the maxillary incisors to the sella-nasion line is increased in the finger-suckers and the angle between the long axis of the maxillary and mandibular incisors is reduced.

(e) The apical base of the maxilla is anteriorly displaced in the finger-suckers.

The effects that thumb- and finger-sucking have on the mandibular incisors is still very controversial. Gardiner (1956) was of the opinion that the lower incisors were retroclined by thumb- and finger-sucking habits. Backlund (1963) observed an increased incidence of children with proclined and mandibular incisors among thumb- and finger-suckers in comparison with normals. Taft and Hempstead (1966) also found a tendency of proclination of the mandibular incisors in 35 finger-sucking children aged five to eleven years. They also observed a prolongation of the mandibular and maxillary dental arches, and that the occlusal plane had tilted upwards in the anterior portion and downwards in the posterior.

It appears that a significant factor in the proclination of the maxillary incisors and of a change in the maxilla is in the disturbances of growth and eruption brought about by a thumb- or finger-sucking habit. The eventual effects that these abnormal oral habits have on the dentofacial structures of any one individual is of course widely varied

because of the multitude of variables associated with each.

2.7 Summary of the literature review

It is apparent from the literature review that the process of growth and development of the dentofacial complex is a very complicated and integrated process. Hellman (1927, 1932) was one of the first to recognize the role of growth and development in bringing about proportional changes of the face because of differential growth rates in different parts of the dentofacial complex.

With the advent of cephalometrics by Broadbent (1931) and Hofrath (1931), a new standardized technique was developed whereby different skeletal and dentoalveolar measurements could be made. By 1937, Broadbent had published his first series of diagrams illustrating an orderly growth pattern of the face of a normal child. The early 1940's marked a great era of cephalometric advancement. It was during these years that a great deal of work was done in studying the internal and facial morphology of individuals and formulating opinions on the pattern of growth and development of the facial complex. Brodie (1946) published an article which is still a classic today. In this, he noted that the facial growth patterns for each individual, regardless of the general growth trend, still possessed a wide variation.

Traditionally, orthodontists tried to identify portions of the dentofacial complex related to malocclusions by studying the dysplasia in the anteroposterior dimension (Downs, 1948, Reidel, 1952; Steiner, 1953). Wylie (1946) studied the relationship between ramus height, dental height, overbite, and noted the differences in total face height and lower face height in open and closed bite cases.

It became evident that controversy over the pattern of facial growth and its relationship to different facial types was of great concern. Studies by Bjork (1962, 1963, 1969), Lande (1952) and Schudy (1963, 1964) have demonstrated how different variations in growth do occur between facial regions and that such variations produced rotations of the mandible in different directions. Enlow (1975) and Lavergne and Gasson (1976) demon-

strated that the apparent constancy of the downward and forward facial growth pattern was not necessarily a result of regular increments of growth.

The particular influence that abnormal oral habits such as thumb- and finger-sucking have had on the dentofacial complex has long been recognized. Swinehart, in 1938, noted a variety of problems associated with these habits and observed that the effects were dependent upon forces exerted by the thumb or fingers, the intensity, and the duration of the habit. The damage to the developing dentition has been shown to vary considerably depending upon the particular sample and variables studied by any researcher.

Klein (1952) noted that most of the damage to the dentition occurred during the mixed dentition stage and that little permanent damage occurred if the pressure habits were discontinued prior to four years of age.

The relationship of thumb- and finger-sucking to the development of an anterior open-bite has been studied extensively. Swindler and Sassouni (1962) studied open-bites in rhesus monkeys and concluded that there seemed to be an elongation of the pre-maxillary dental arch in thumbsuckers. Hapak (1964) noted that the axial inclination of the upper incisors and subsequent open-bite was directly related to thumb-sucking.

Individual variation appears to be the rule, not the exception. Of the two most prominent dental manifestations of vertical skeletal disharmonies, open-bites are the most commonly associated with cases of thumbsucking.

CHAPTER 3

MATERIALS AND METHODS

3.0 Materials and Methods

3.1 Composition of sample

The patient sample for this study was derived from two previous studies. The first of these studies was designed to evaluate the effectiveness of the various methods of arresting thumbsucking (Haryett *et al.,* 1967). This initial study began in 1964 on children with thumbsucking habits in the City of Edmonton, Alberta. All of the subjects were four years of age and older and were persistent thumbsuckers. Lateral cephalograms along with other dental records were taken and were available for each child. There were 66 patients in the original study. These children were randomly divided into different groups in order to study the various methods of arresting thumbsucking. Records on each of these patients were taken one year after the commencement of treatment.

The second study (Lamont, 1976) was designed to evaluate the dental changes on a longitudinal basis of children with an arrested thumbsucking habit. Lamont's (1976) recent cephalometric study was based on 33 of the original patients from Haryett's (1967) study were recallable for long-term records. All of these subjects had been persistent thumbsuckers and displayed clinical changes resulting from the habit. These patients had all been treated with crib therapy ranging from three months to one year in duration. Any subject who had received or was receiving orthodontic treatment was eliminated from the study unless suitable pre-orthodontic treatment records could be obtained.

The present sample was derived from the 33 patients for whom the three sets of records were on file. The sample consisted of 25 females and 8 males, all Caucasoids. For a breakdown on mean age of current sample, see Table I.

A description of the current sample based on skeletal classification and sex are found in Table II. A further breakdown of the 33 patients was established by using all pre-treatment lateral cephalometric radiographs. The patients were categorized and classified into three types of growth patterns as follows:

(a) Horizontal-vertical (H–V) – the mandibular plane to the sella nasion (S–N) plane

TABLE I

The Range and Mean Ages of the Sample

Sex	Treatment Stage		
	Pre-Treatment	Post-Treatment	Long-Term
Female (n = 25)	6.36 * 4.17 – 9.58	7.40 5.33 – 10.58	14.92 10.41 – 21.08
Male (n = 8)	6.86 4.50 – 10.00	7.76 5.33 – 10.91	17.04 11.58 – 20.25
(n = 33)	6.48	7.49	15.43

*in years

TABLE II

Distribution of Sample Based on Angle Classification and Sex

Sex	Angle Classification			Total
	Class I	Class II	Class III	
Male	6	1	1	8
Female	7	18	0	25
Total	13	19	1	33

TABLE III

Distribution of Sample Based on Growth Pattern and Sex

Sex	Growth Pattern			Total
	H-V	V	H	
Male	4	4	0	8
Female	12	12	0	25
Total	16	16	1	33

ranged from 28° to 36°.

(b) Vertical (V) – the mandibular plane to the S–N plane was greater than 36°.

(c) Horizontal (H) – the mandibular plane to S–N plane was less than 28°.

See table III for a complete breakdown of the current sample based on the particular type of growth pattern.

3.2 Control data

The comparative data base for this study consisted of age-related average linear dimensions derived from *An Atlas of Cranial Facial Growth* (Riolo *et al.,* 1974). Eighty-three individuals, 47 males and 36 females, made up the population from which cephalometric data was derived. The population had attended an elementary school in Ann Arbor, Michigan, over a period ranging from their sixth to their sixteenth birthdays. Serial lateral cephalometric radiographs were taken of each patient until their sixteenth birthday. All of the records for the control data were taken on birthdays when the birthdate fell during the school year. The data of the children having birthdays outside of the school year were collected on their half-year birthdate. The comparative data base age groups were determined by including in each age, cephalograms taken six months before a birth month through five months after a birth month. The quantities tabulated are the age of measurement (i.e., six to sixteen years), the sample size at each age, the estimated mean value at each age, and the estimated standard deviation. None of these subjects were treated orthodontically previous to starting or during the course of the project. For a more complete breakdown of the Michigan control sample for each variable, see Appendix, Figures 14 to 25.

3.3 Comparison of sample with control data

The linear measurements for each of the skeletal and dentoalveolar vertical dimensions in the sample used in this study were analyzed over three time periods: pretreatment; post-treatment, and long-term. Each of the linear variables measured in the present study were compared at the three different observation periods to the Michigan control

sample. Table IV gives a complete breakdown of the number of patients in the present study that fell within the different age categoreis for each of the three observation periods.

The subjects of the sample study were all converted to absolute figures since the Michigan control study did not use fractions of a year. For example, a patient in the present study who was 5.8 years was considered a six-year-old. All of those between 5.5 and 6.49 years were considered six-year-olds. The study sample had patients ranging from four to ten years of age at the pre-treatment observation period. Since the Michigan control study started at age six years, all those that were below that age were omitted at the pre-treatment stage. At the post-treatment stage, the study sample ranged from five to eleven years so only those subjects between six and eleven years were included. At the long-term observation period, the study sample had patients ranging from ten to twenty years but since the Michigan control sample provided data only until sixteen years of age, all of those over sixteen at this stage had to be eliminated.

3.4 Cephalometric radiography

3.4.1 Technique

Serial cephalometric radiographs were obtained from the files of the 33 patients (Lamont, 1976). Pre-treatment, immediate post-treatment, and long-term radiographs were all taken with the conventional technique developed by Broadbent (1931). All standardized lateral cephalograms were taken with a General Electric machine set to 300 M.A. with all subjects positioned in a head holder with ear rods. The anode to film distance was 150 centimeters. All of the radiographs were taken with the patient in their normal centric occlusion. Each patient's file contained three serial cephalometric radiographs which were used for analysis. These radiographs were labelled as follows:

(a) Pre-treatment–Each patient had a lateral cephalometric radiograph taken prior to insertion of the crib.

(b) Post-treatment–Each patient had a lateral cephalometric radiograph taken one year after appliance insertion regardless of the length of the crib therapy.

TABLE IV

Distribution of Sample According to Age Category

	Age Categories (yrs)																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Pre-Treatment	3	10	7	3	3	3	4										
Post-Treatment		4	8	8	3	3	2	5									
Long-Term							1		2	2	1	9	6	1	2	4	5
Numbers of Patients																	

(c) Long-term—Records were repeated at a mean of 7.95 years later by Lamont (1976).

Tracings of the pre-treatment, post-treatment, and long-term cephalograms were made by the same individual on .003 acetate paper with a sharp 3H lead pencil. All bilateral structures were averaged before being traced (Broadbent *et al.,* 1975). All linear measurements were determined to the nearest 0.5mm. There were no corrections made for linear magnification factor.

3.4.2 Cephalometric points and landmarks

The following landmarks were determined for each lateral cephalogram (see Figures 1 and 2):

3.4.2.1 Sella (S)

The point representing the centre of the sella turcica (pituitary fossa).

3.4.2.2 Nasion (N)

The mid-point of the front-nasal suture at its most anterior margin.

3.4.2.3 Spheno-ethmoidal junction (SE)

The junction of the planum sphenoidale and the greater wing of sphenoid.

3.4.2.4 Articulare (AR)

The point of intersection of the images of the posterior border of the mandible and the temporal bone.

3.4.2.5 Anterior Nasal Spine (ANS)

The tip of the anterior nasal spine which forms the most anterior projection of the floor of the nasal cavity.

3.4.2.6 Posterior Nasal Spine (PNS)

The tip of the posterior nasal spine which is formed by the united projecting ends of the posterior borders of the palatal processes of the palatal bones.

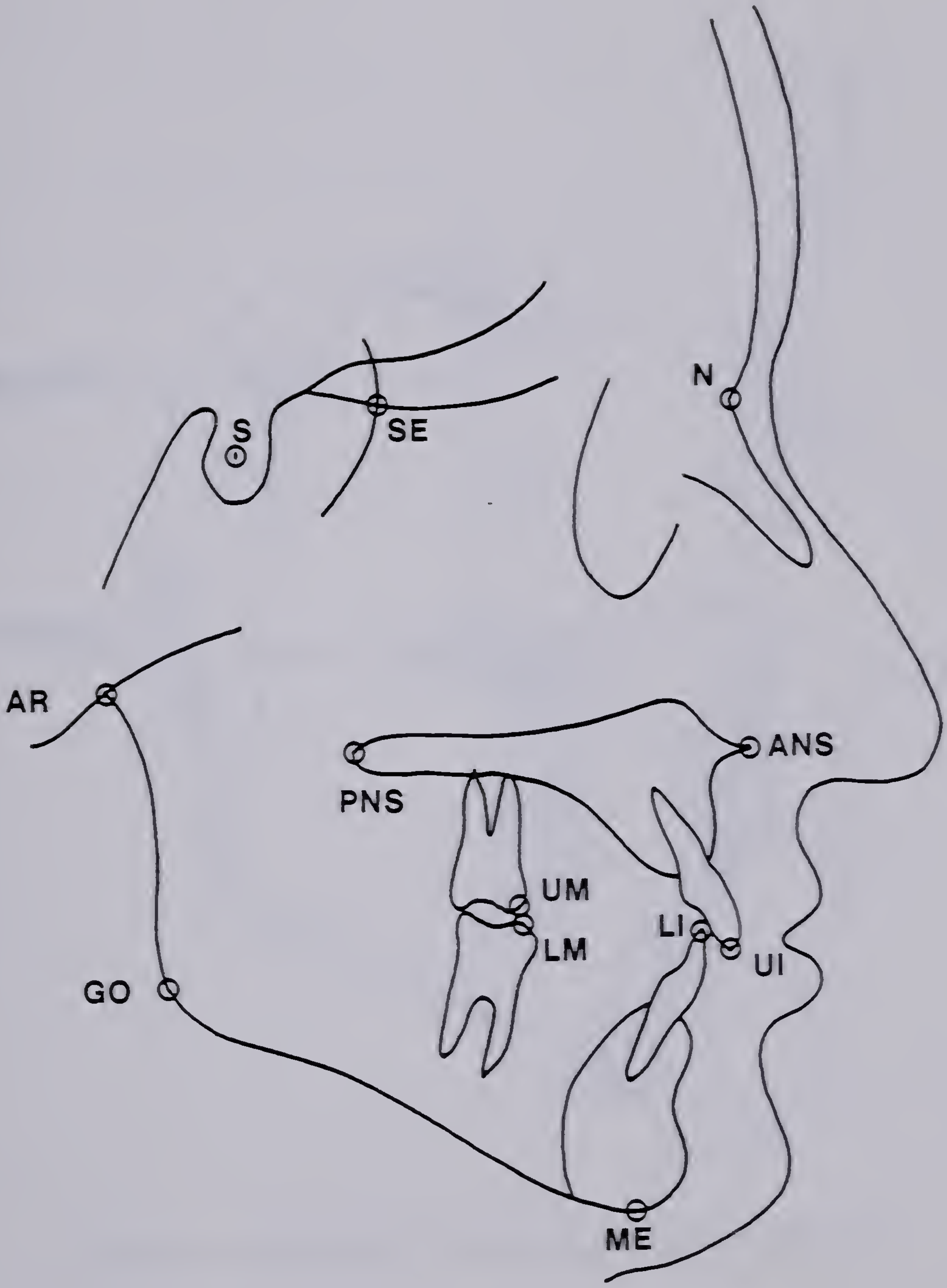


Figure 1 Cephalometric points and landmarks

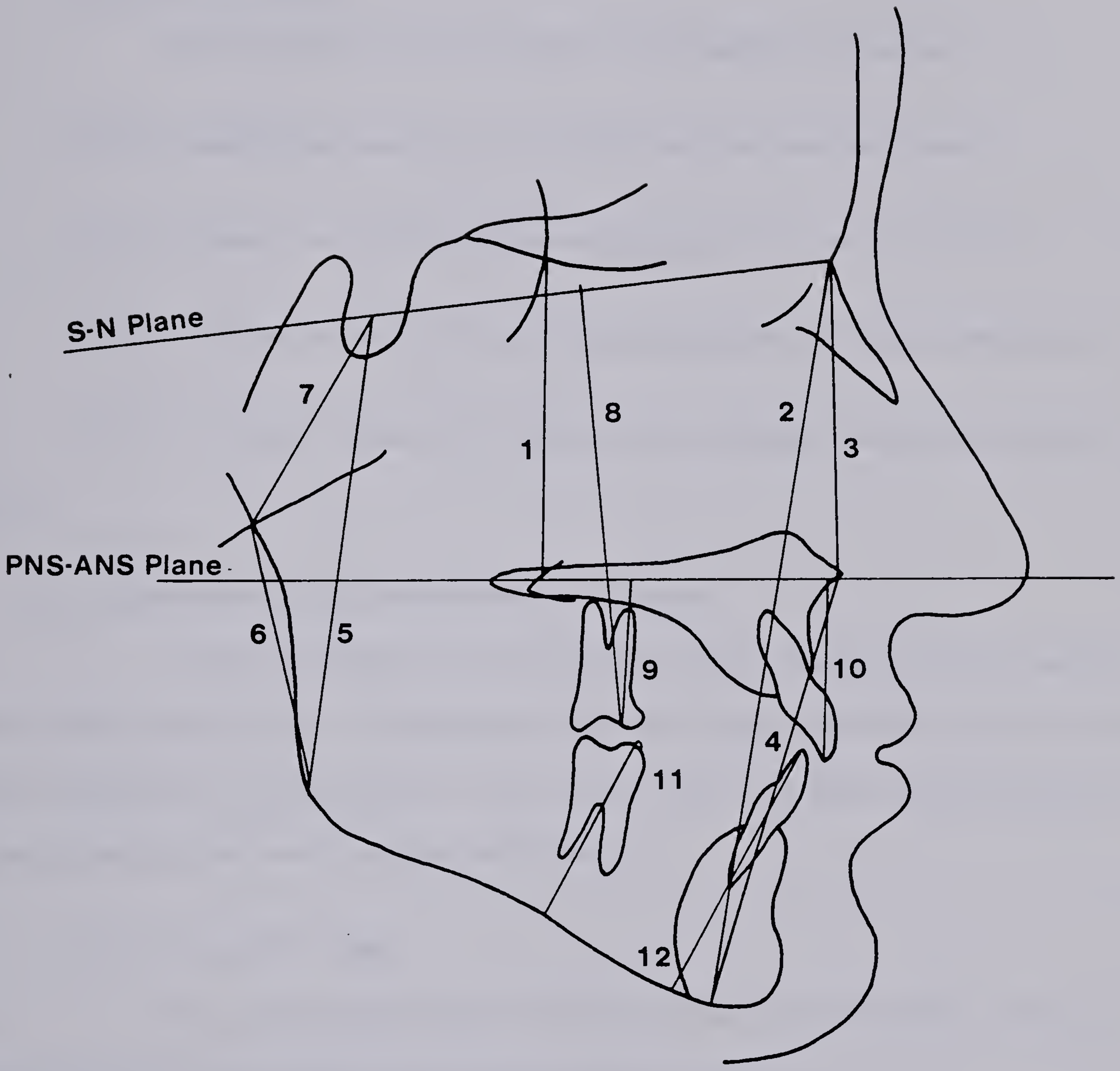


Figure 2 Linear skeletal and dentoalveolar measurements

3.4.2.7 **Gonion** (GO)

The external angle of the mandible formed by bisecting the angle formed by tangents to the posterior border of ramus and the inferior border of the mandibular body.

3.4.2.8 **Menton** (ME)

The most inferior midline point on the mandibular symphysis.

3.4.2.9 Mesiobuccal cusp tip of the maxillary left first permanent molar.

3.4.2.10 Mesiobuccal cusp tip of the mandibular left first permanent molar.

3.4.2.11 The incisal edge of the most anterior positioned maxillary central incisor.

3.4.2.12 The incisal edge of the most anterior positioned mandibular central incisor.

3.4.3 Linear skeletal and dento-alveolar measurements

A series of skeletal and dento-alveolar linear measurements were made of each lateral cephalogram. All measurements were made with a millimeter ruler and each linear measurement was determined to the nearest 0.5mm. The linear skeletal and dento-alveolar measurements were as follows (see Figure 2):

3.4.3.1 SE ⊥ PNS–ANS

The perpendicular distance from the palatal plane (ANS–PNS) to the junction of the planum sphenoidale and the greater wing of sphenoid.

3.4.3.2 N–ME

The distance from nasion to menton (anterior total face height).

3.4.3.3 N–ANS

The linear distance from nasion to anterior nasal spine (anterior upper face height).

3.4.3.4 ANS–ME

The linear distance from anterior nasal spine to menton (anterior lower face height).

3.4.3.5 S–GO

The linear distance from sella to gonion (posterior total face height).

3.4.3.6 AR–GO

The linear distance from point articulare to gonion (lower posterior face height).

3.4.3.7 S–AR

The linear distance from sella to point articulare (upper posterior face height).

3.4.3.8 UM ⊥ S–N

The perpendicular distance from the mesiobuccal cusp tip of the maxillary left first molar to the sella-nasion plane.

3.4.3.9 UM ⊥ ANS–PNS

The perpendicular distance from the mesiobuccal cusp tip of the maxillary left first molar to the palatal plane.

3.4.3.10 UI ⊥ ANS–PNS

The perpendicular distance from the tip of the most anterior positioned maxillary central incisor to the palatal plane.

3.4.3.11 LM ⊥ GO–ME

The perpendicular distance from the mesiobuccal cusp tip of the mandibular left first molar to the mandibular plane (GO–ME).

3.4.3.12 LI ⊥ GO–ME

The perpendicular distance from the incisal edge of the most anterior positioned mandibular central incisor to the mandibular plane.

3.4.3.13 (UM ⊥ S–N) - (UM ⊥ ANS–PNS)

A derived measurement used to measure the amount of maxillary sutural growth. It is the perpendicular distance from the maxillary left first molar to the S–N plane minus the perpendicular distance from the maxillary left first molar to the palatal plane.

3.5 Statistical analysis

The major statistical analysis used in this study was one of confidence intervals. It was assumed that the data of the Michigan control study was normally distributed, therefore, one would expect 95% of the data values to fall within 1.96 standard deviations of the mean. Means and standard deviations were calculated for each variable. For each of the different skeletal and dentoalveolar vertical dimensions, a 0.95 level of confidence was established at three separate observation periods. The grand means for each variable in the study sample were compared to that of the Michigan control in order to determine if there was a significant difference between the sample and the control at each stage of observation.

The formula for the 0.95 level of confidence was:

$$\text{Mean} \pm \left[\frac{\text{S.D.} \times 1.96}{\sqrt{\text{sample size}}}\right]$$

CHAPTER 4

RESULTS

4.0 Results

The results of this study are discussed under separate sections corresponding to the different linear measurements or variables that were used to compare this sample of 33 patients to the Michigan control sample of Riolo *et al.* (1974). Each of the individual variables correspond to different vertical measurements that are used to assess abnormalities of malocclusions in the vertical dimension (Wylie, 1952; Coben, 1955; Schudy, 1966; Creekmore, 1967; Nahoum, 1971; Biggerstaff *et al.,* 1977; Opdebeeck *et al.,* 1978). Only eleven of the original thirteen variables for the skeletal and dentoalveolar dimensions were used. Because of the smallness of the sample, of which only eight of 33 patients were males, there was no differentiation made between males and females when compared to the control sample.

Appendix I, Figures 14 through 25, reveals the age specific descriptive statistics for each of the comparative variables that were used.

The results of the skeletal and dentoalveolar vertical skeletal dimensions are discussed under separate sections. The first section deals with the skeletal variables associated with vertical skeletal assessment. The second section deals with the dentoalveolar variables. In each section, the sample was compared at the 0.95 level of confidence established for the control. Since the sample was studied over three time periods, a comparison of each variable over three time periods was made to assess if the abnormal thumbsucking sample at Time 1 (pre-treatment) was significantly different at the 0.05 level. The variables were studied at post-treatment (Time 2) and long-term (Time 3) and compared to the control. The overall trends for each of the variables through three time periods were made.

The linear cephalometric measurements for the entire sample at each of the three phases of treatment are presented in Table V.

Table V

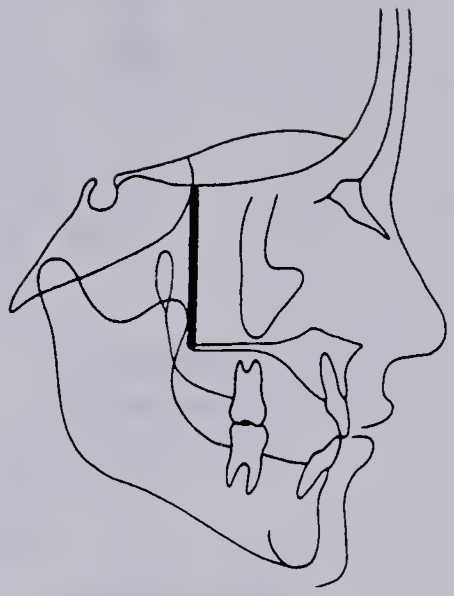
Linear Cephalometric Measurements for the Entire Sample

	Pre-treatment Means and S.D. (mm)	Post-treatment Means and S.D. (mm)	Long-term Means and S.D. (mm)
Skeletal Measurements (mm)			
SE–PNS–ANS	40.60 ± 3.32	40.60 ± 3.20	47.43 ± 3.88
N–ME	96.93 ± 7.22	103.28 ± 7.38	119.05 ± 8.61
N–ANS	44.83 ± 2.48	45.67 ± 3.53	55.05 ± 5.51
ANS–ME	59.28 ± 5.31	59.55 ± 4.92	66.17 ± 5.83
S–GO	62.08 ± 4.79	62.56 ± 5.06	75.05 ± 6.09
AR–GO	37.23 ± 3.53	37.93 ± 3.45	45.57 ± 4.74
S–AR	29.00 ± 3.44	29.78 ± 3.59	34.17 ± 3.75
Dentoalveolar Measurements			
UM ⊥ ANS–PNS	17.53 ± 1.87	17.81 ± 1.90	22.38 ± 2.84
UI ⊥ ANS–PNS	23.25 ± 2.70	24.07 ± 2.73	29.05 ± 2.69
LM ⊥ GO–ME	26.98 ± 1.99	27.10 ± 2.05	30.52 ± 3.17
LI ⊥ GO–ME	34.63 ± 3.09	34.19 ± 2.96	40.21 ± 3.51

4.1 Skeletal Measurements

4.1.1 SE–ANS–PNS

Ethmoid Registration Point–Palatal plane



The general trend at pre-treatment (Time 1), as illustrated in Figure 3(a), showed that the thumbsucking patients, before the insertion of the cribs, tended to have a significantly shorter measurement representing the sutural growth areas of upper posterior face, than the control group at the 0.95 level of confidence. Of the original group at pre-treatment, only the eight-year-olds were within the confidence interval.

The post-treatment records (one year later) showed the same general trend as initially. Only at age ten did the sample fall within the 0.95 confidence interval [see Figure 3(b)].

At Time 3 (long-term), as represented by Figure 3(c), the experimental group appeared to be more like the control group. The sample at ages ten, twelve, thirteen and fourteen years were all within the 0.95 confidence interval while at the fifteen- and sixteen-year-old age categories they were below the range.

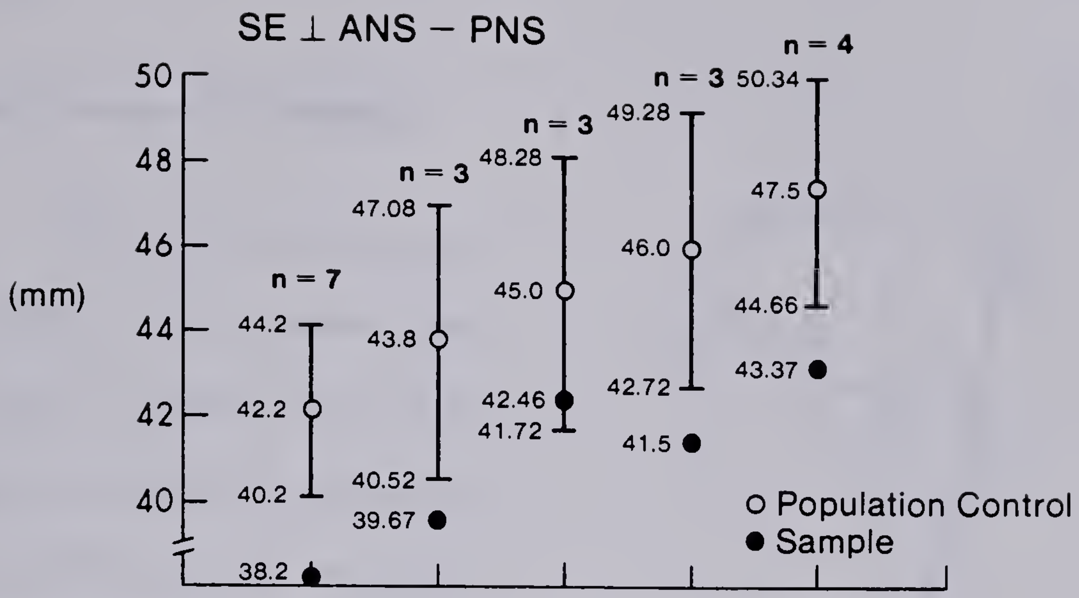


Figure 3a Time 1 (pre-treatment)

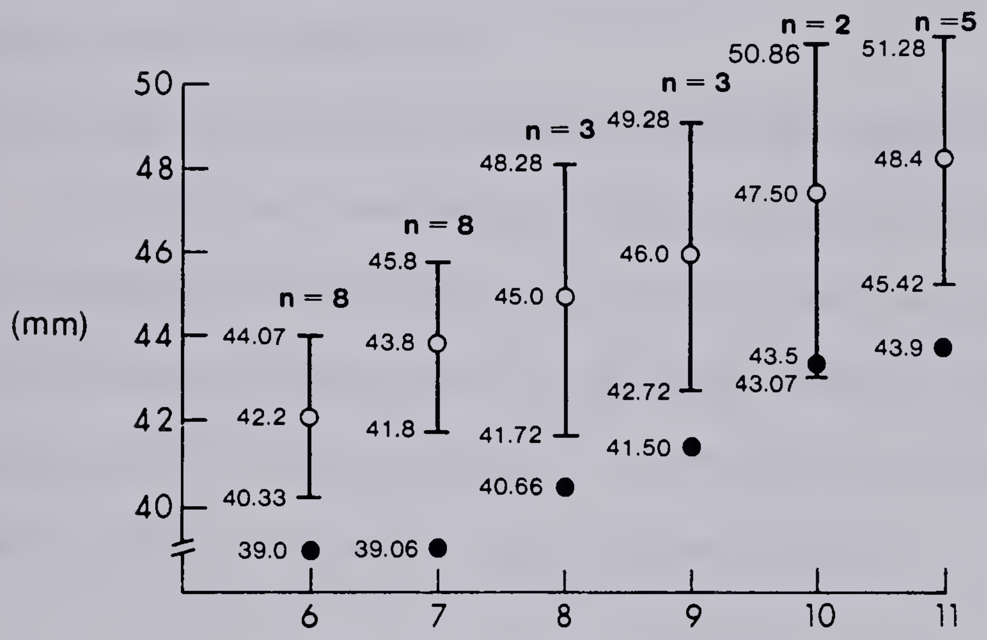


Figure 3b Time 2 (post-treatment)

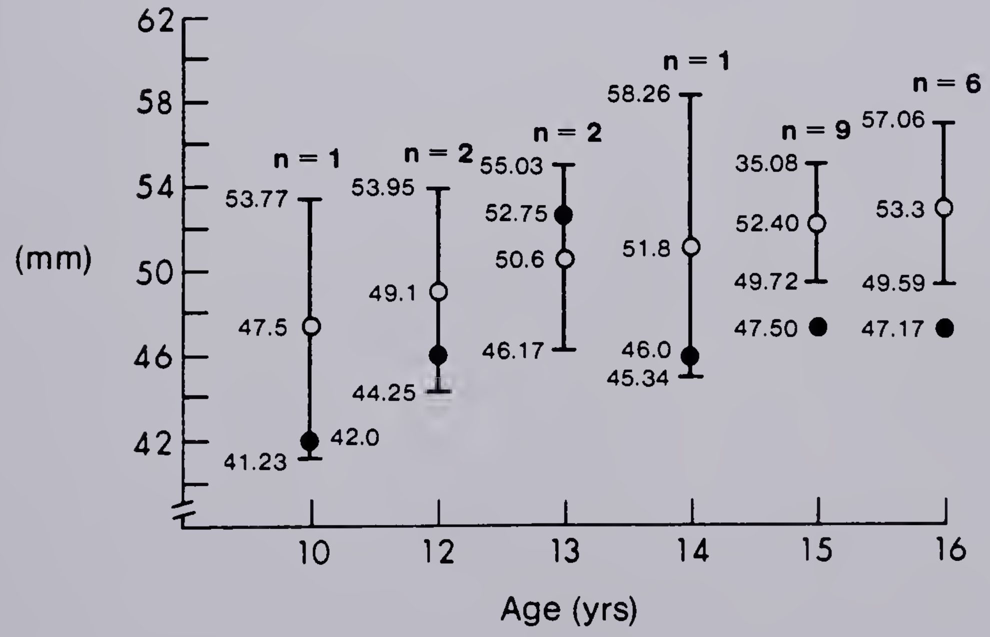
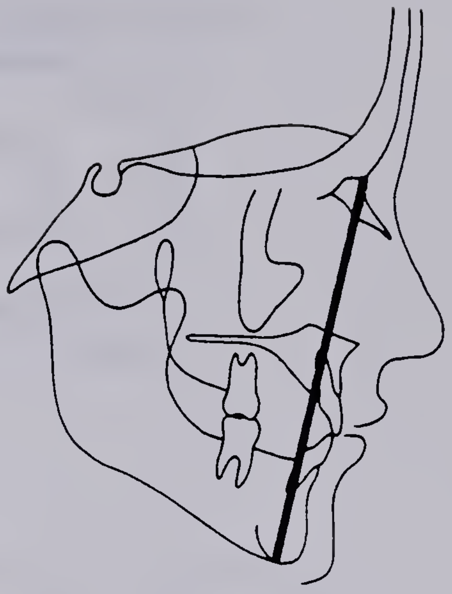


Figure 3c Time 3 (long-term)

4.1.2 N–ME

(Total Anterior Face Height)



The total anterior face height (TAFH) of the thumbsucking group at Time 1, as shown in Figure 4(a), was significantly smaller than the control group at the 0.95 level of confidence. Four out of the five age categories at the pre-treatment stage were below the range and only at age nine years did the sample fall within the confidence interval.

One year later, when the cribs had been removed (Time 2), the same trend was observed [see Figure 4(b)]. In Figure 4(c) (Time 3), there was a general trend towards being more like the normal control group. At ages twelve, thirteen and fourteen, the sample was well within the 0.95 level but at ages ten, fifteen and sixteen years they were significantly below the confidence interval for that of the control group.

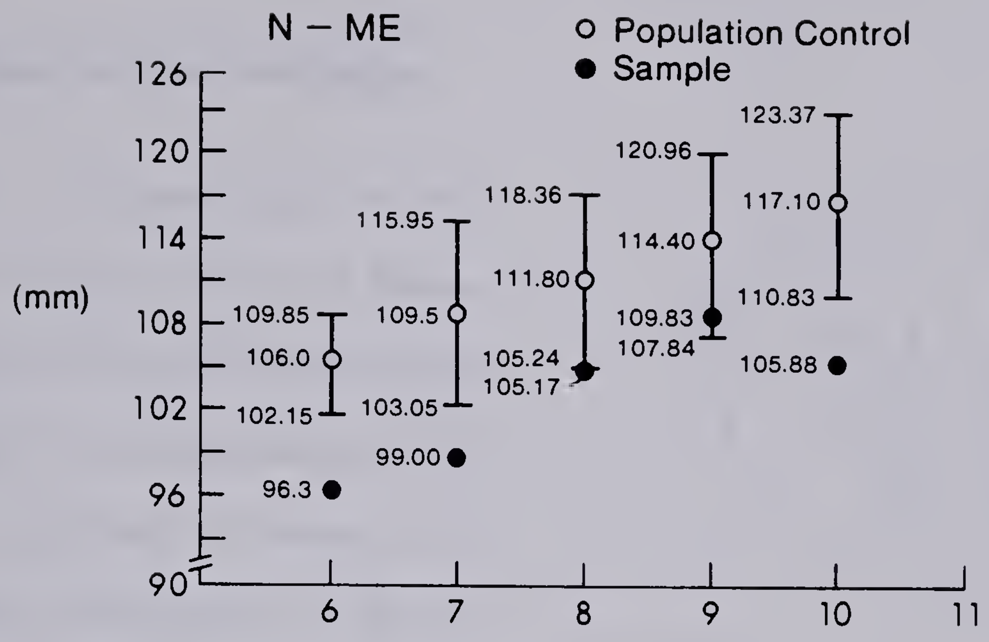


Figure 4a Time 1 (pre-treatment)

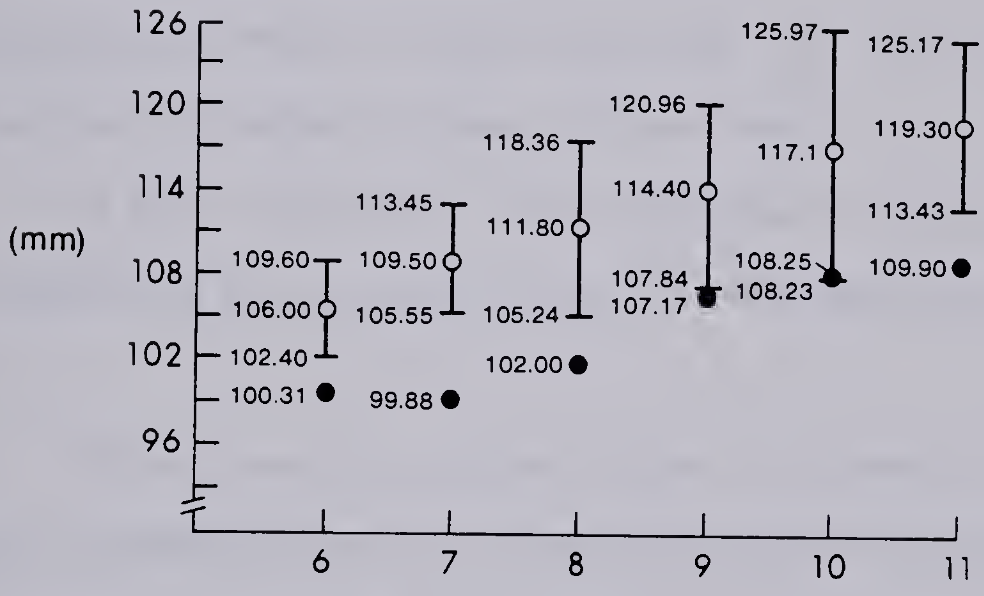


Figure 4b Time 2 (post-treatment)

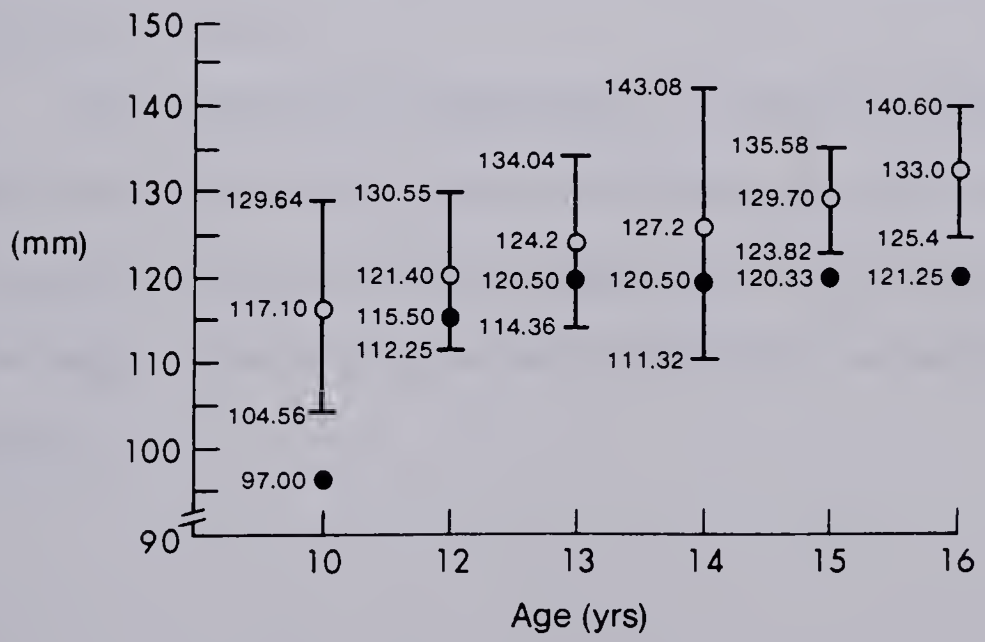
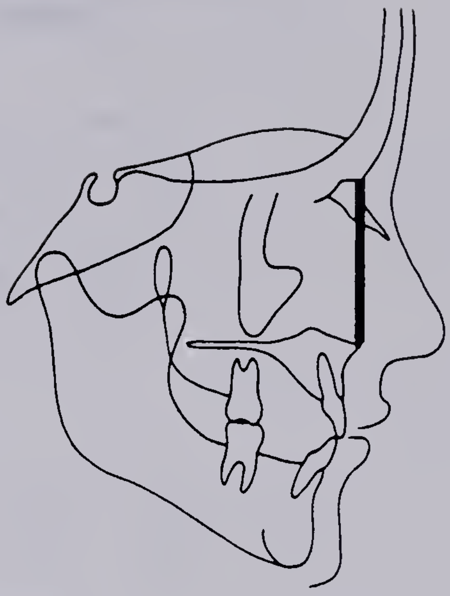


Figure 4c Time 3 (long-term)

4.1.3 N–ANS

(Upper Anterior Face Height)



The results for the third variable, N–ANS, are shown in Figures 5(a)(b) and (c). From Figure 5(a), it was noted that the thumbsucking sample showed a significant difference in relation to the control group. At ages six, seven and ten years (pre-treatment), the sample was significantly below the control group at the 0.95 level while only at ages eight and nine years were they within the normal confidence interval.

At Time 2 [Figure 5(b)], only those at ages six and nine years were within the normal range while those at ages seven, eight, ten and eleven years were significantly below.

The long-term data, as shown in Figure 5(c), showed that there was a more general trend towards being closer to the normal control group. Only at ages ten and sixteen years was the sample outside of the 0.95 confidence interval. Even at these ages, they were only slightly below the range.

The general trend for this variable (N–ANS) showed that the upper anterior face height of the thumbsucking sample was significantly shorter than that of the control sample at both the pre- and post-treatment stages. Only at Time 3(long-term) did the upper anterior face height of the sample group tend to fall within normal limits as compared to the control group.

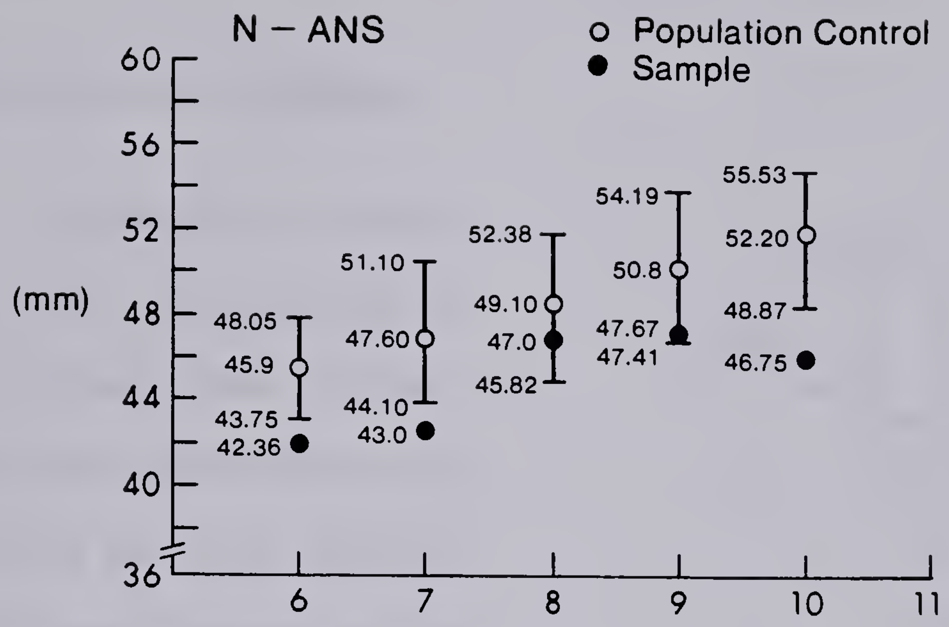


Figure 5a Time 1 (pre-treatment)

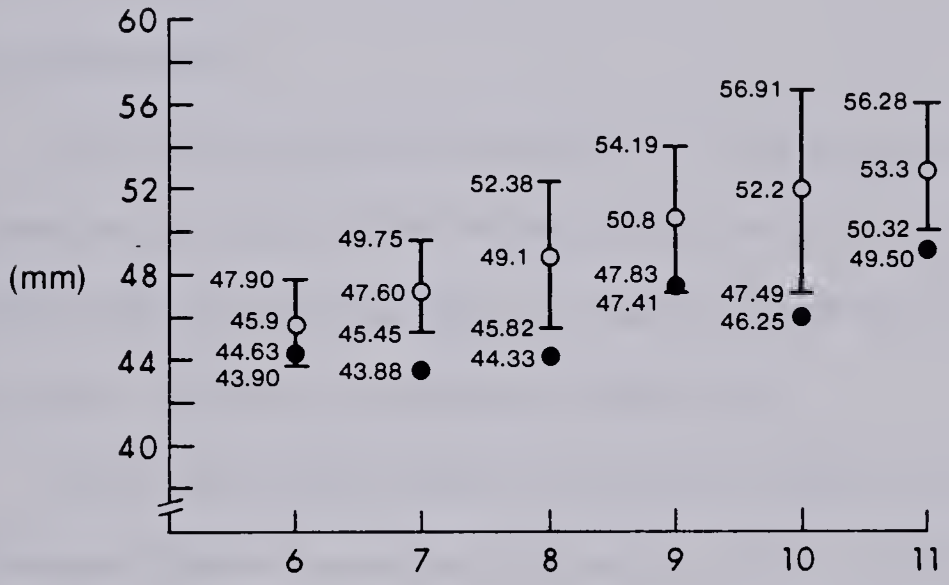


Figure 5b Time 2 (post-treatment)

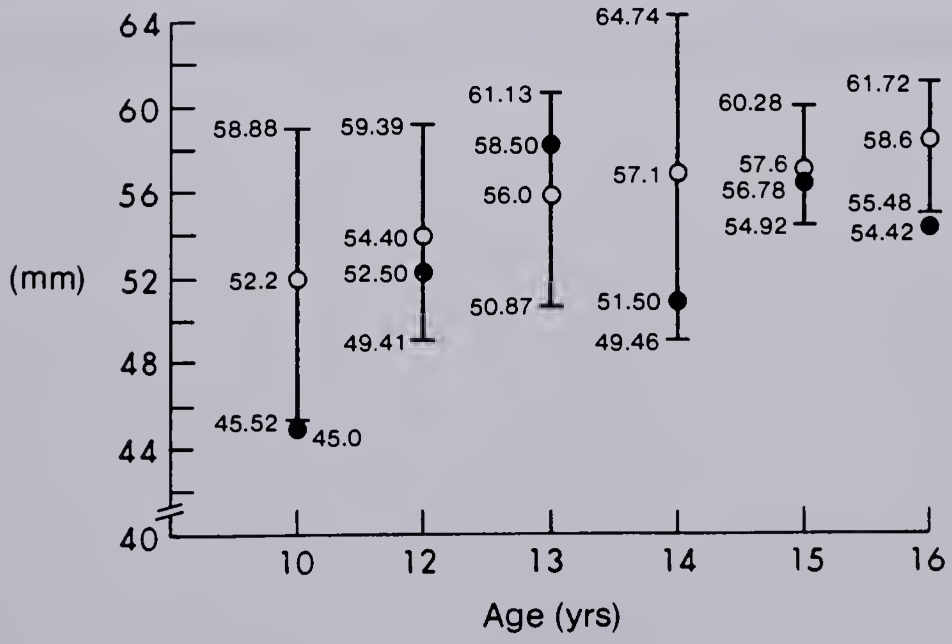
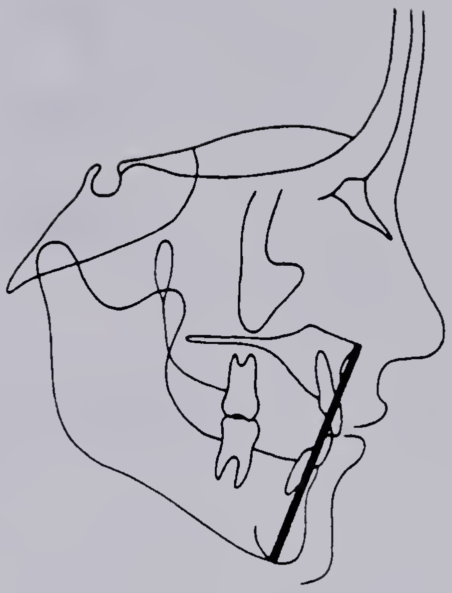


Figure 5c Time 3 (long-term)

4.1.4 ANS–ME

(Lower Anterior Face Height)



Examination of the lower anterior face height (ANS–ME) revealed that the experimental group at Time 1 (pre-treatment) had a significantly smaller lower anterior face height than those of the control group. This trend was consistent for all age categories except the nine-year-olds [Figure 6(a)].

At the post-treatment stage (Time 2), there appeared to be a tendency at ages eight, nine and ten years towards becoming more like the control group. At ages six, seven and eleven years, the lower anterior face height still appeared to be smaller than the control group at the 0.95 level of confidence [Figure 6(b)].

The long-term result (Time 3), as shown in Figure 6(c), revealed that at ages twelve, thirteen and fourteen years the experimental group was well within the range of normal. At age ten and again at the fifteen- and sixteen-year-old age categories, the lower anterior face height appeared to be shorter than that of the control group.

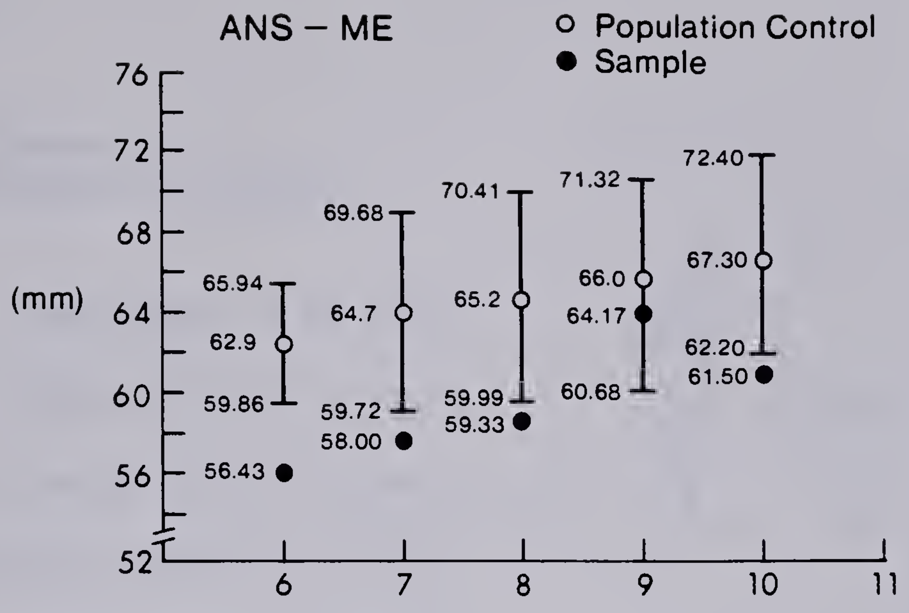


Figure 6a Time 1 (pre-treatment)

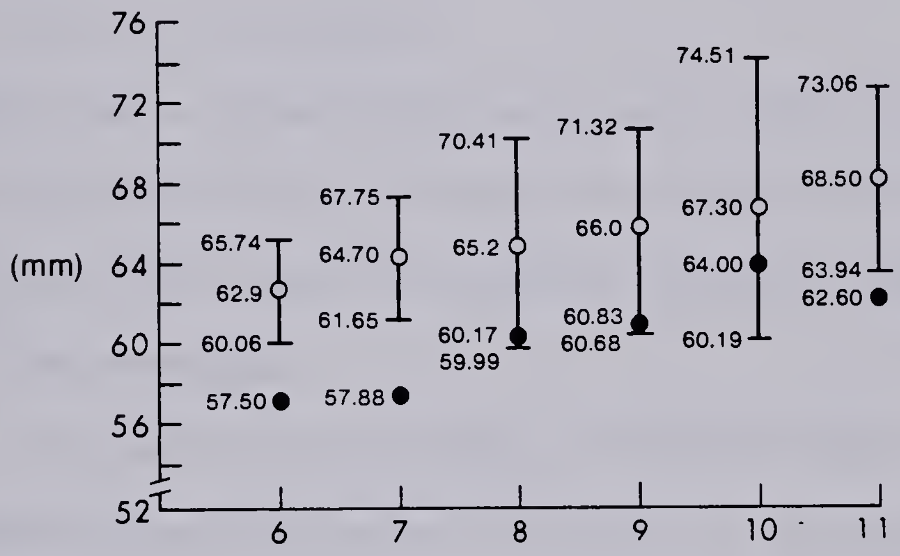


Figure 6b Time 2 (post-treatment)

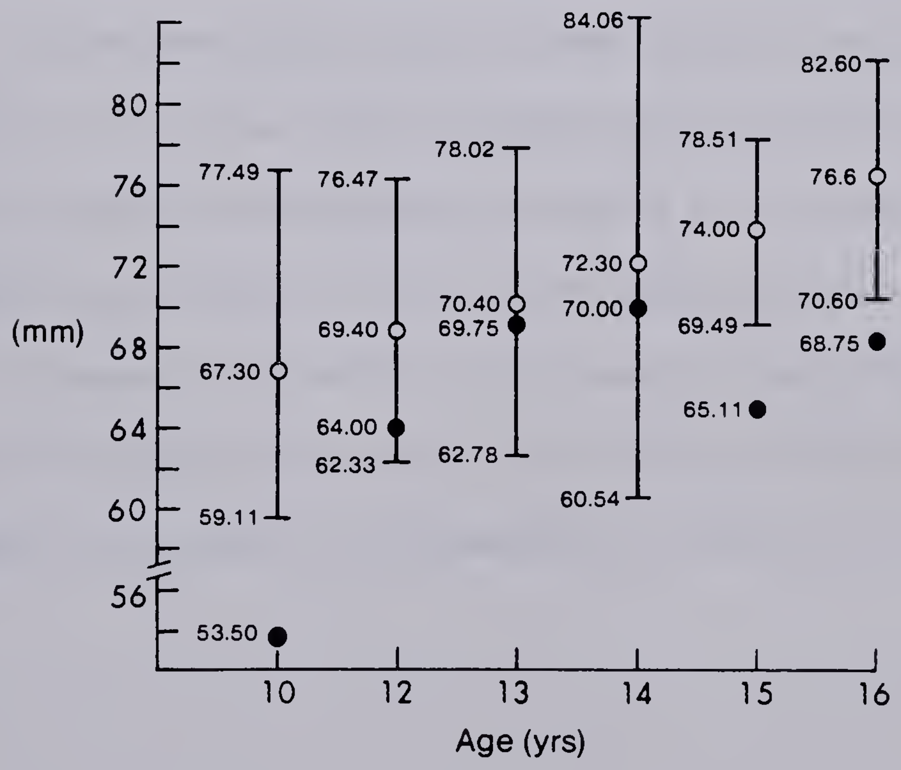
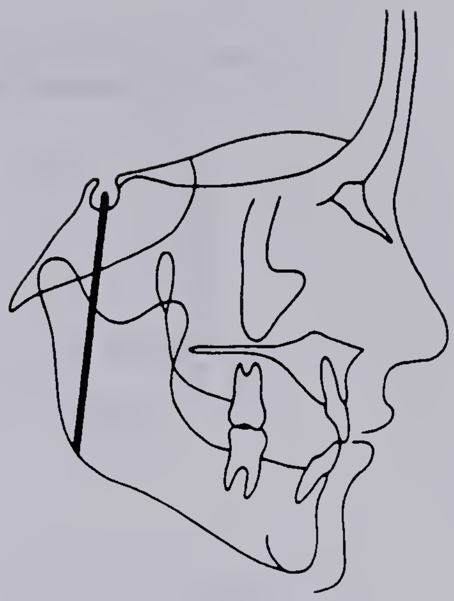


Figure 6c Time 3 (long-term)

4.1.5 S–GO

Sella–Gonion
(Total Posterior Face Height)



Examination of the total posterior face height (S–GO) of the thumbsucking sample at Time 1 (pre-treatment) indicated that this group was significantly shorter than the control group at the 0.95 level of confidence [see Figure 7(a)]. Only at age seven years was the sample within the range of normal. It is interesting to note that both the total anterior face height (N–ME) as shown in Figures 4(a)(b) and (c), and total posterior face height are significantly shorter than the control group at the pre-treatment stage.

The post-treatment stage (Time 2), as shown in Figure 7(b), showed a slight tendency towards being more like the normal control group. At ages six, seven, nine and eleven years, the total posterior face height was slightly below that of the control group.

The long-term stage (Time 3) revealed that the experimental group was similar to that of the control group. Only at age sixteen [see Figure 7(c)] was there a considerable drop in the mean S–GO measurement. The mean S–GO measurement dropped from 78.55mm at fifteen years of age to 73.83mm for the sixteen-year-olds.

In general, the trend for the total posterior face height over the three time periods was for the experimental sample to be less than the control at Time 1 and Time 2. At Time 3, there was a tendency for the sample to fall within the 0.95 level except at age sixteen years.

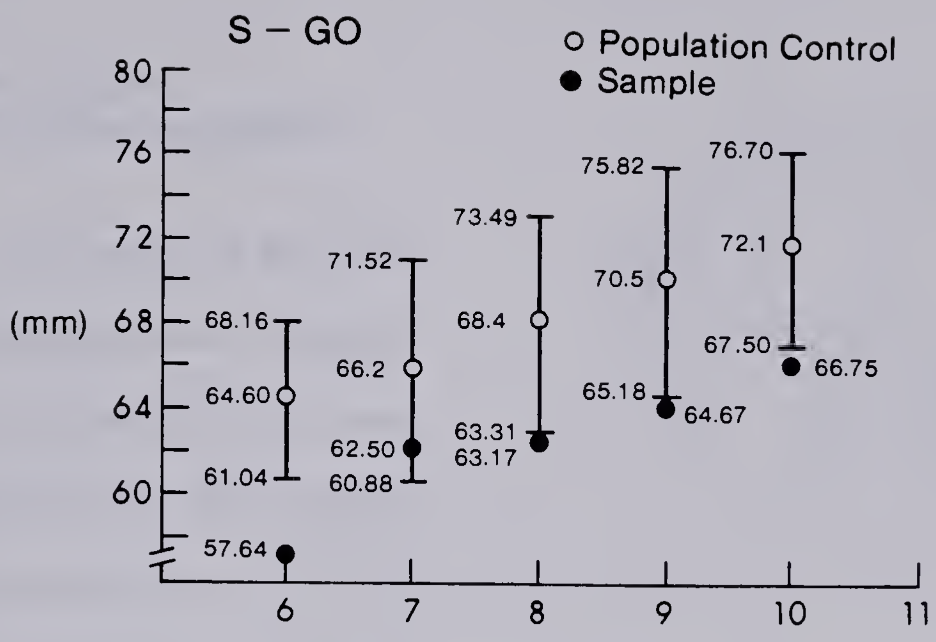


Figure 7a Time 1 (pre-treatment)

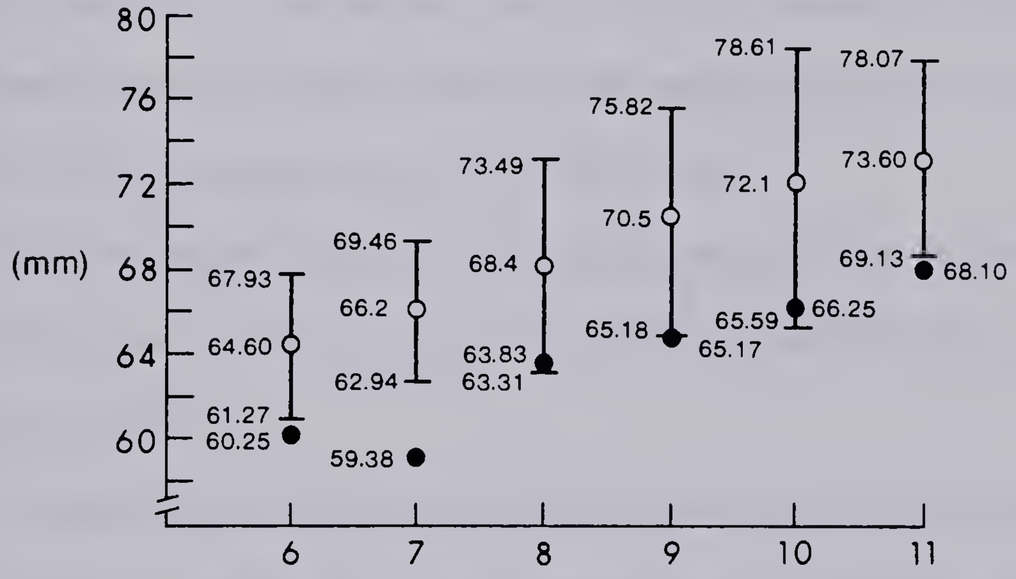
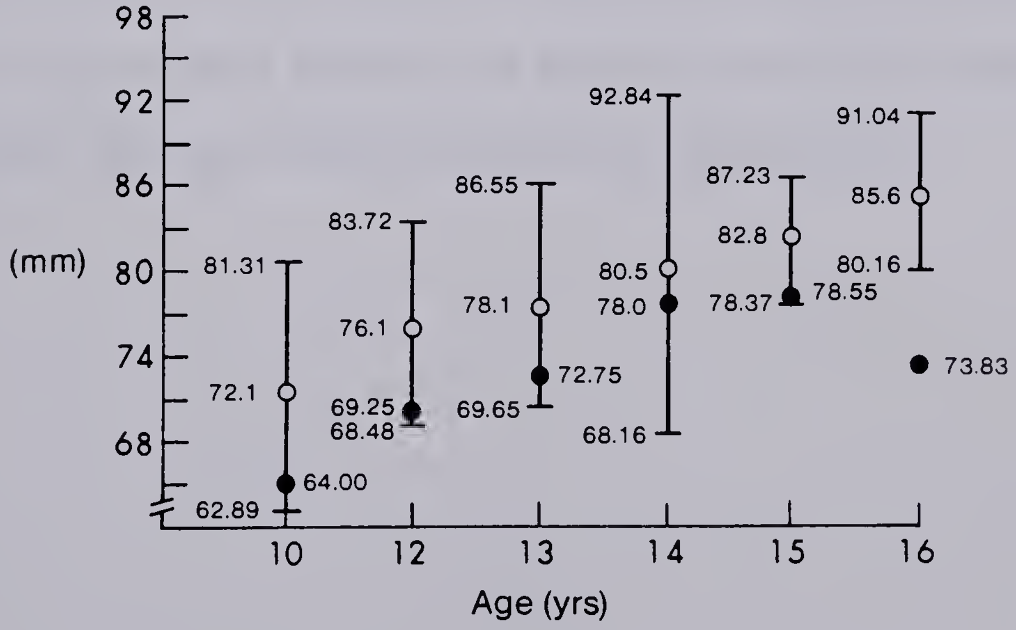


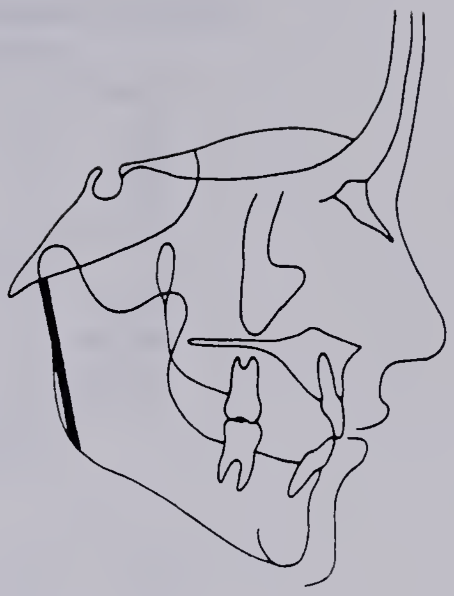
Figure 7b Time 2 (post-treatment)



Figre 7c Time 3 (long-term)

4.1.6 AR–GO

Articulare–Gonion
(Lower Posterior Face Height)



The results of the sixth vertical skeletal dimension are illustrated in Figures 8(a)(b) and (c). The lower posterior face height (AR–GO) measurements at pre-treatment (Time 1) in general tended to be slightly less than the normal control group. Only at ages six and ten years did the sample fall within the 0.95 confidence interval, however, at seven, eight and nine years the means for the sample were just slightly below that of the control group [see Figure 8(a)].

At post-treatment (Time 2), six-, seven- and eight-year-olds were significantly smaller than the control while the nine-, ten- and eleven-year-olds were well within the range of normal [see Figure 8(b)].

At Time 3 [see Figure 8(c)], there was a trend after twelve years for the experimental group to be more like the normal control group. The sample was well within the 0.95 confidence interval at twelve, thirteen, fourteen and fifteen years of age, however at sixteen years of age the lower posterior face height was much shorter than the control sample at 43.08mm. This was considerably below the confidence interval.

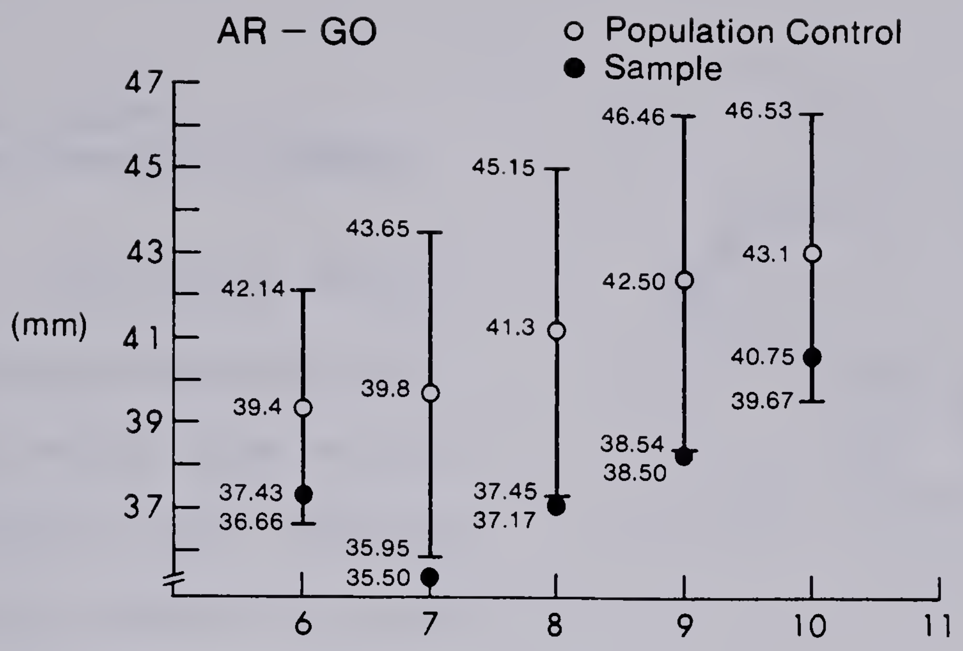


Figure 8a Time 1 (pre-treatment)

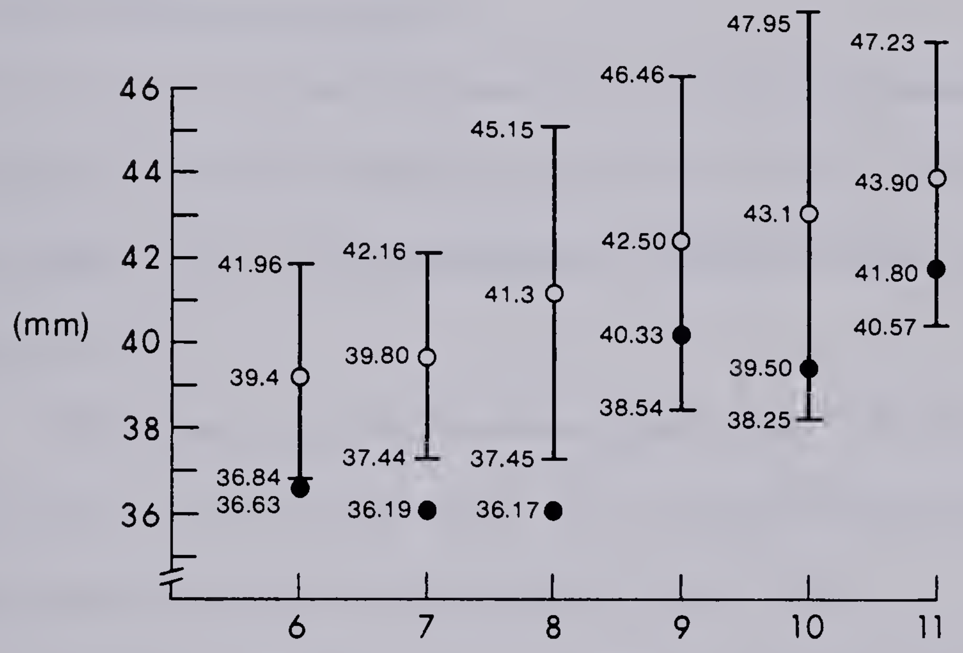


Figure 8b Time 2 (post-treatment)

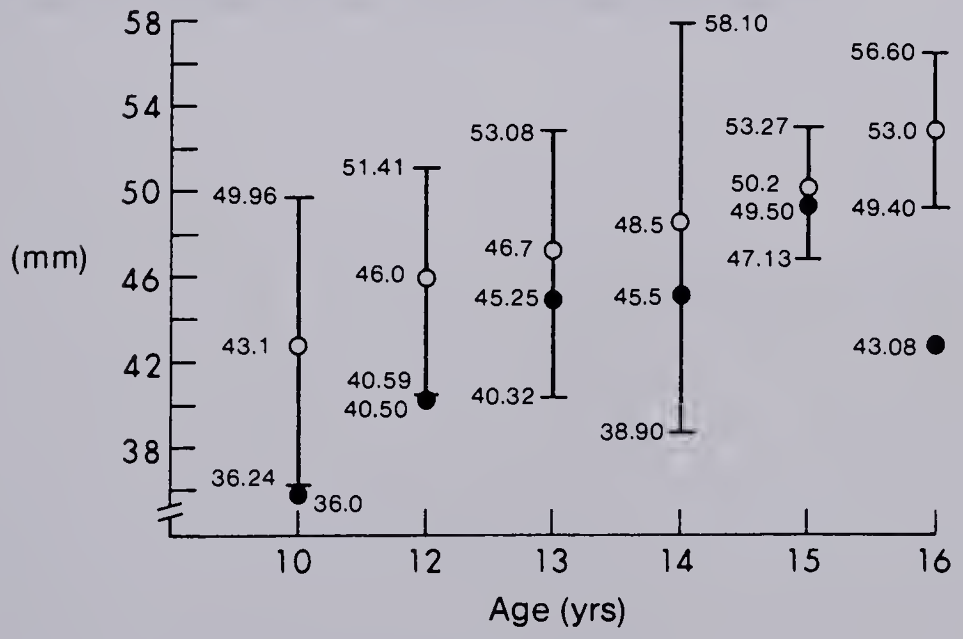
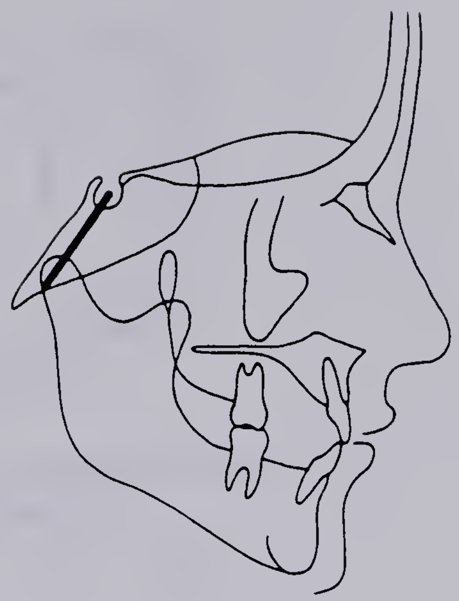


Figure 8c Time 3 (long-term)

4.1.7 S–AR

Sella–Articulare
(Upper Posterior Face Height)



The results of this vertical skeletal dimension are shown in Figures 9(a)(b) and (c). There was a noticeable difference in the relationship of the upper posterior face height (UPFH) of the thumbsucking sample at pre-treatment to that of the control group. The UPFH of the experimental group tended not to be significantly different from that of the normal control group at the 0.95 level of confidence. Only at age six years was the mean UPFH measurement less than the control sample [see Figure 9(a)].

The trend at the post-treatment stage (Time 2) also showed very little difference between six and eleven years of age. All of the age categories were within the confidence interval except those at seven years of age [see Figure 9(b)].

The long-term stage (Time 3) showed no significant difference between the study sample and the control group at all of the age categories.

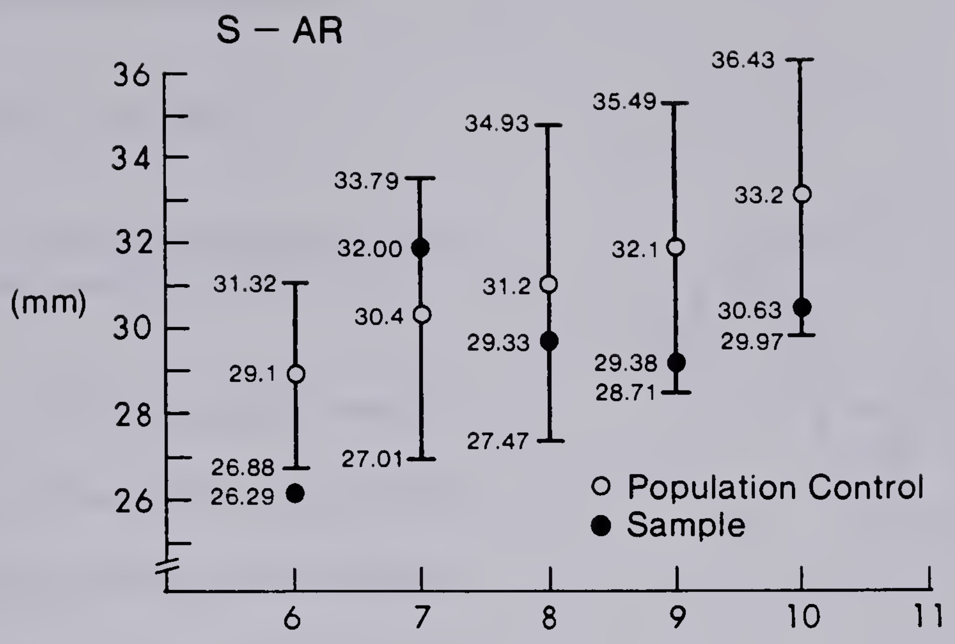


Figure 9a Time 1 (pre-treatment)

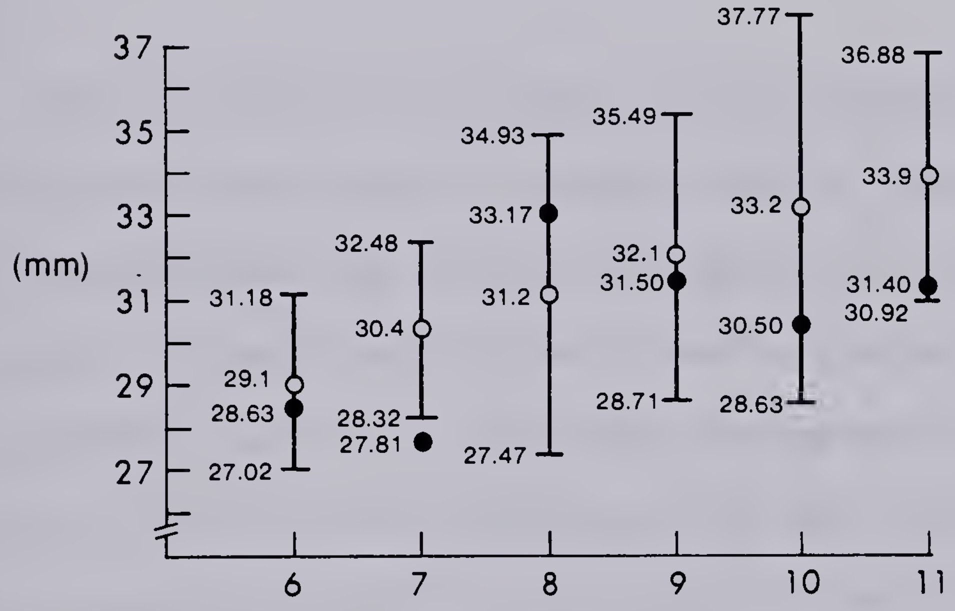


Figure 9b Time 2 (post-treatment)

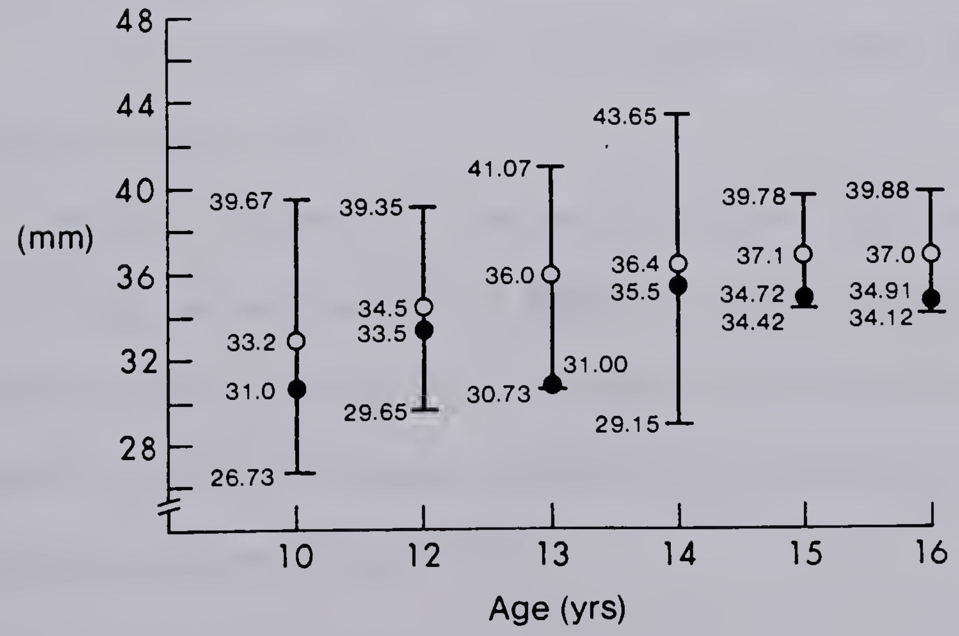
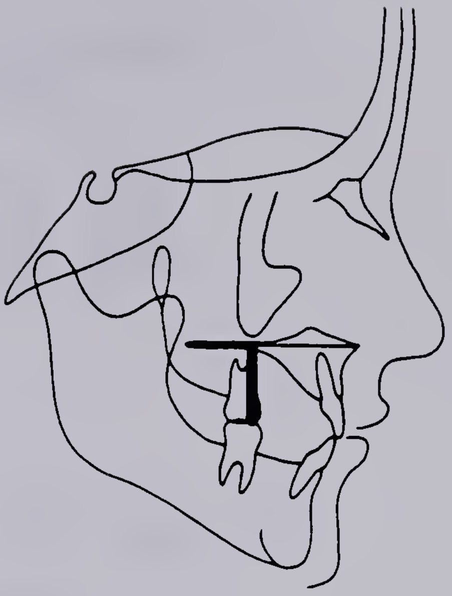


Figure 9c Time 3 (long-term)

4.2 Dentoalveolar measurements

4.2.1 UM ⊥ ANS–PNS



Upper molar mesial cusp tip perpendicular to palatal plane

The age-specific descriptive statistics of the control sample for each of the four dentoalveolar dimensions are found in Appendix I, Figures 22 through 25.

The first dentoalveolar relationship was the perpendicular distance from the upper first molar to the palatal plane [for illustrated results, see Figures 10(a)(b) and (c)]. The trend at the pre-treatment stage (Time 1) of the thumbsucking sample to the control showed that there was no significant difference between the group as a whole and that of the control group. Only at age six years was the mean measurement for the sample study significantly different from that of the control group. In this case, at age six years, the mean measurement was greater than the 0.95 level of confidence for the control group (16.57mm as compared to 15.34mm).

At Time 2 (post-treatment), the general trend followed the same pattern as it had at Time 1 [see Figure 10(b)].

At Time 3 (long-term) there were a number of differences. In general, the thumbsucking sample was not significantly different from that of the control group. At age ten years, and again at age sixteen years, the sample study showed that the vertical distance from the upper first molar to the palatal plane was shorter than that of the control at the 0.95 level of confidence [see Figure 10(c)].

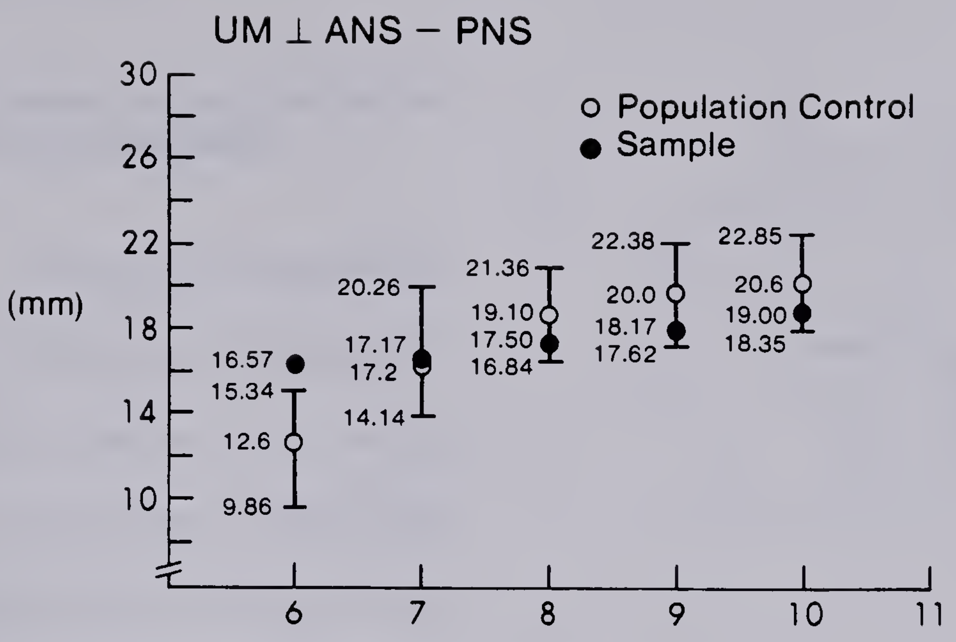


Figure 10a Time 1 (pre-treatment)

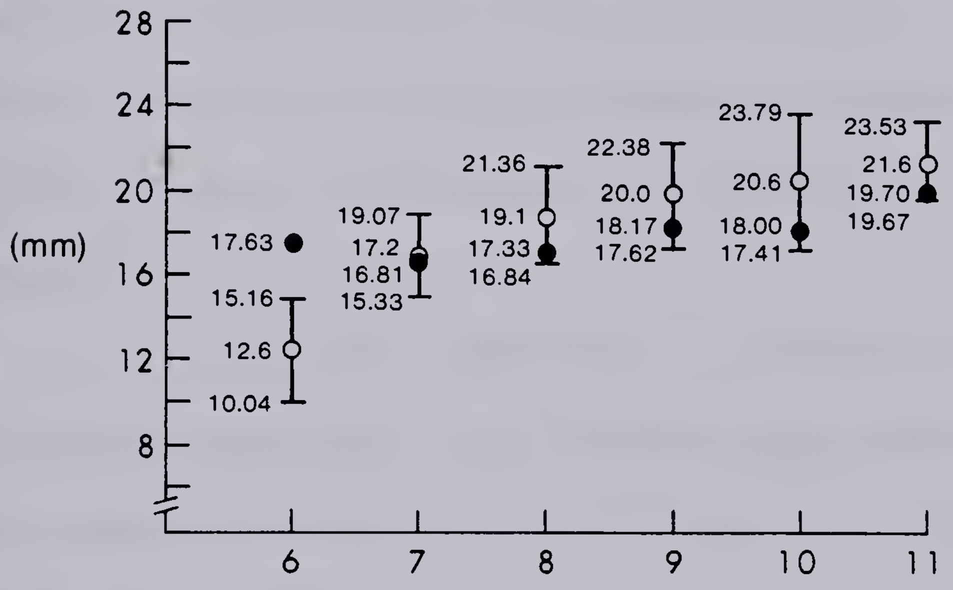


Figure 10b Time 2 (post-treatment)

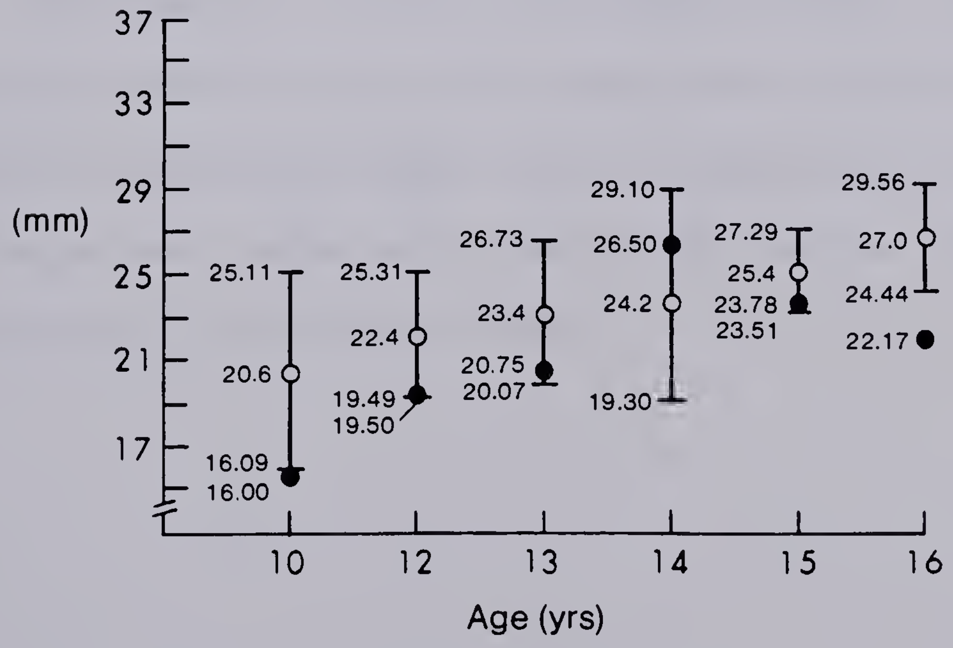
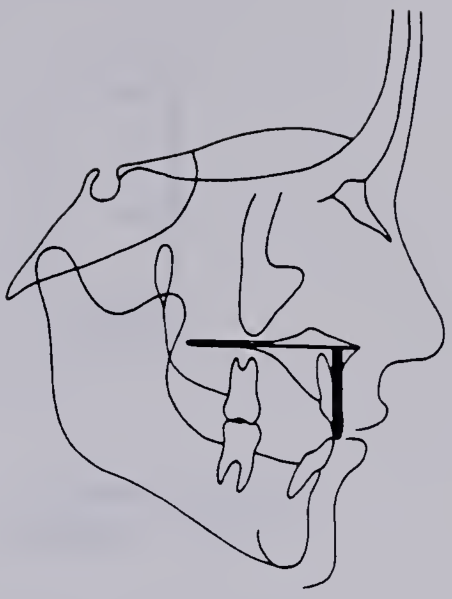


Figure 10c Time 3 (long-term)

4.2.2 UI ⊥ ANS–PNS

Upper incisor incisal edge perpendicular to palatal plane



The second dentoalveolar measurement was the perpendicular distance from the upper incisor tip to the palatal plane [see Figures 11(a)(b) and (c)]. The trend at the pre-treatment stage (Time 1) showed the thumbsucking group was significantly smaller than that of the control group. At ages six, seven, eight and ten years, the distance from the incisor tip to the palatal plane was less than that for the control group. Only those in the nine-year-old age category fell within the 0.95 confidence interval [see Figure 11(a)].

At the post-treatment stage (Time 2), the same general trend continued. There was a much closer relationship of the experimental group to that of the normal control group. At age eight and ten years, the thumbsucking group was within the 0.95 confidence interval [see Figure 11(b)].

The long-term observation period (Time 3) showed a more decisive change towards the normal especially at the twelve-, thirteen- and fourteen-year-old age categories. At age ten years, the dentoalveolar distance from the upper incisor tip to the palatal plane was greater for the study sample than for the control group [see Figure 11(c)]. At ages fifteen and sixteen years, the opposite was found.

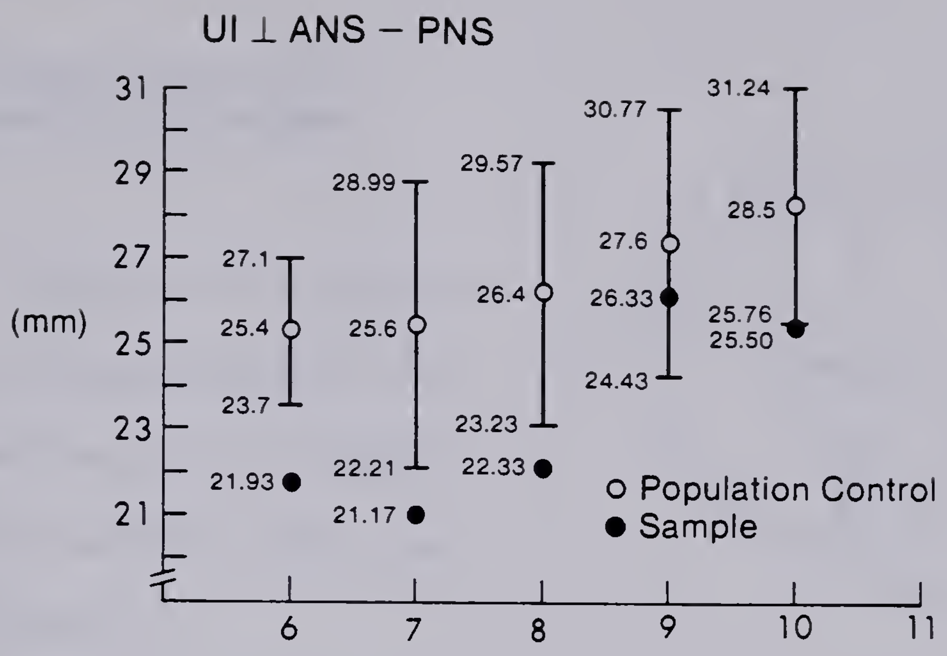


Figure 11a Time 1 (pre-treatment)

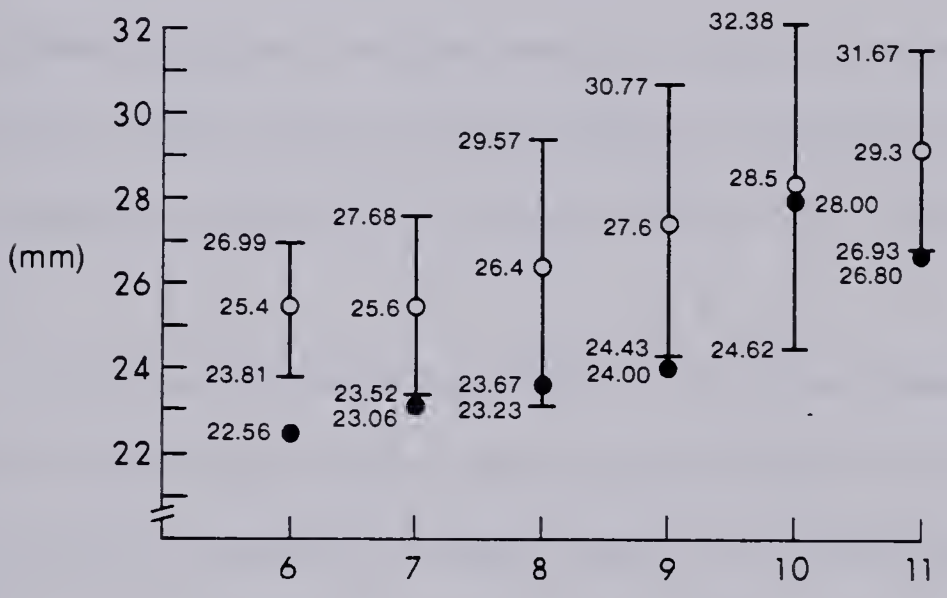


Figure 11b Time 2 (post-treatment)

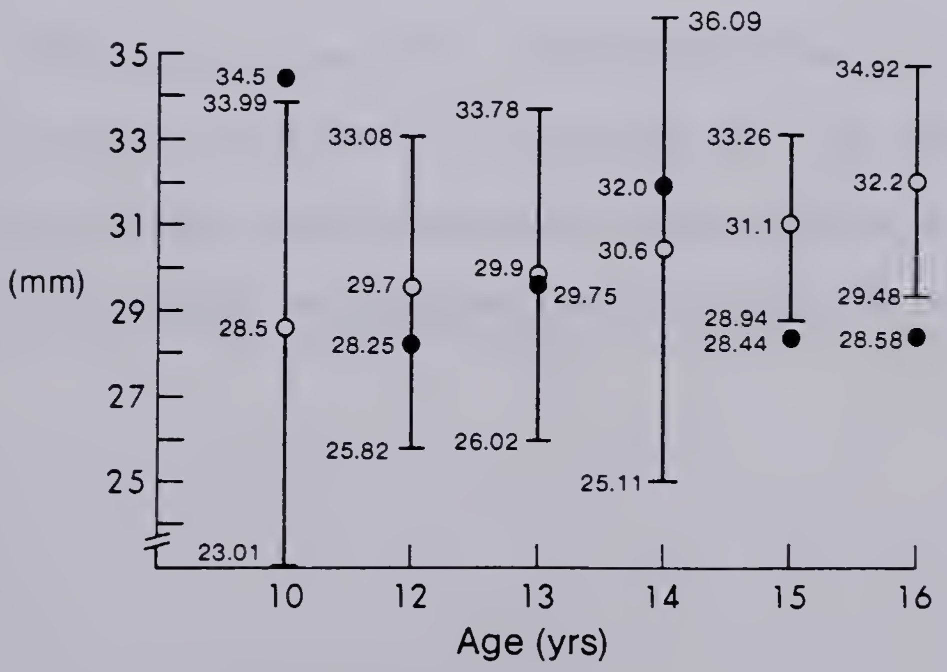
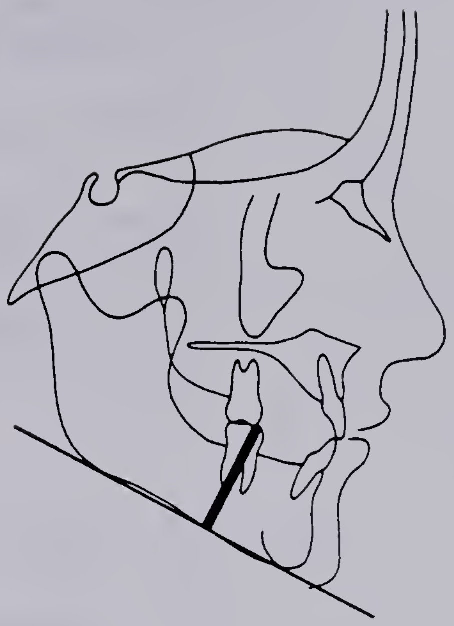


Figure 11c Time 3 (long-term)

4.2.3. LM ⊥ GO–ME

Lower molar mesial cusp tip perpendicular to mandibular plane



The third dentoalveolar measurement was the perpendicular distance from the lower first molar mesial cusp tip to the mandibular plane [see Figures 12(a)(b) and (c)].

At the pre-treatment stage (Time 1), the thumbsucking group at ages seven, eight and ten years were found to have a significantly shorter vertical distance from the molars to the mandibular plane. Those in the six- and nine-year-old age categories were found within the 0.95 confidence interval [see Figure 12(a)].

At the post-treatment stage (Time 2), the general trend was for the study sample to have a significantly shorter mean measurement than that of the control group. Only at ages six and ten years was the sample found to be within the range of normal [see Figure 12(b)].

The long-term stage (Time 3) showed that from ten to fourteen years, the distance from the lower first molar to the mandibular plane was within the 0.95 confidence interval. The fifteen- and sixteen-year-old categories however showed that the same distance in the study sample was significantly less than that of the control group [see Figure 12(c)].

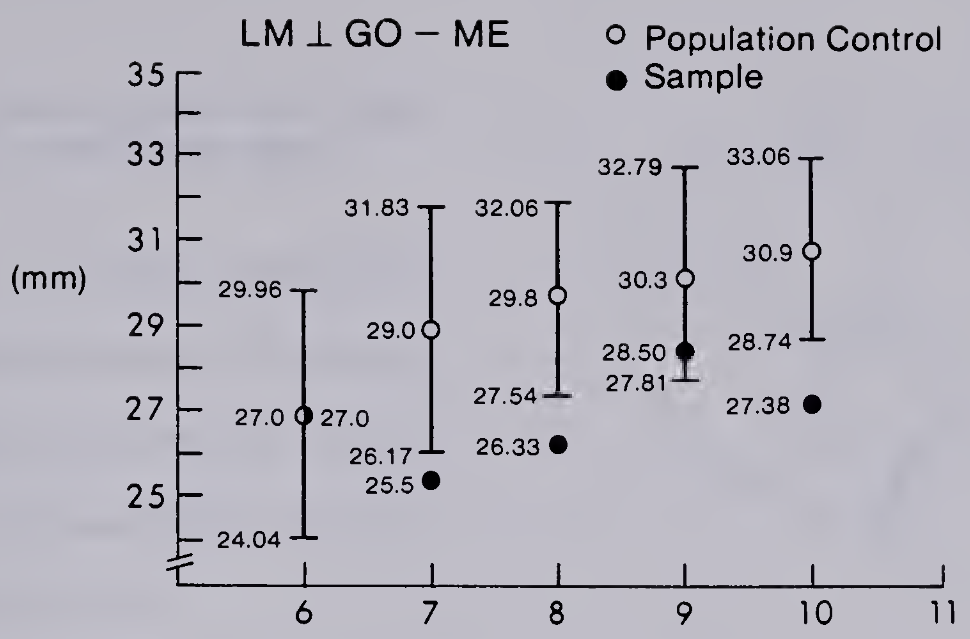


Figure 12a Time 1 (pre-treatment)

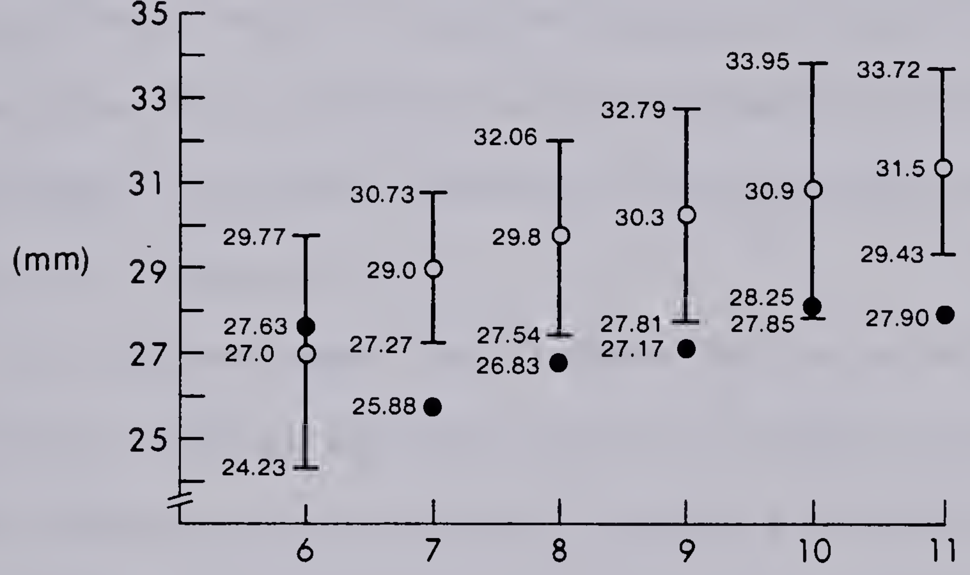


Figure 12b Time 2 (post-treatment)

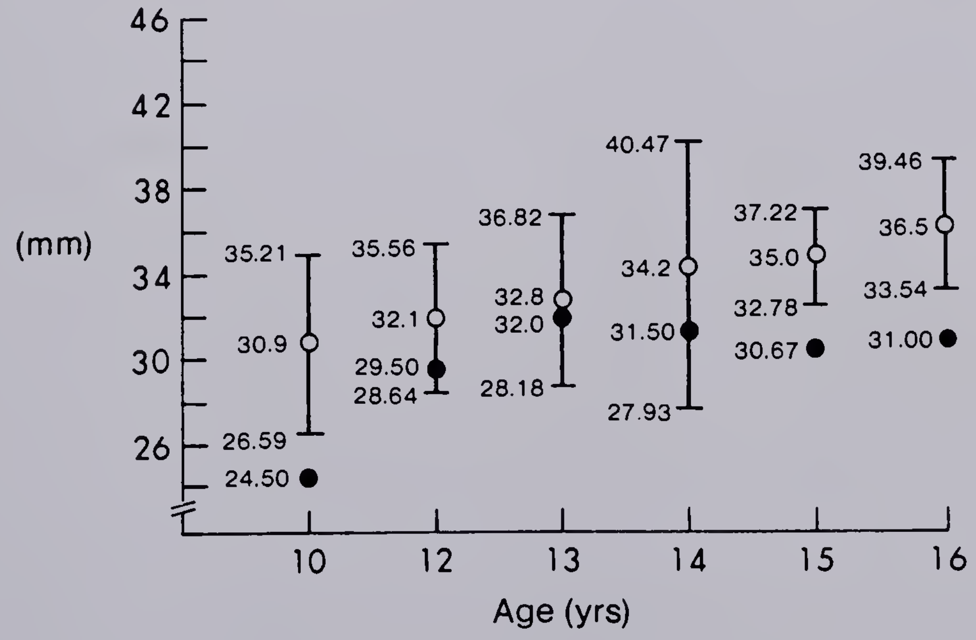
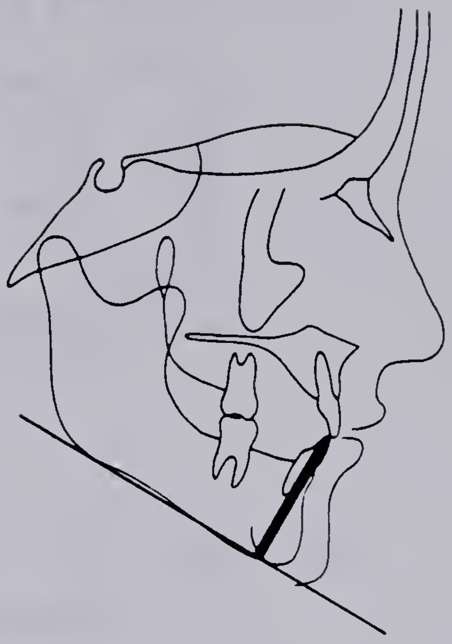


Figure 12c Time 3 (long-term)

4.2.4 LI ⊥ GO–ME



Lower incisor incisal edge perpendicular to mandibular plane

The fourth dentoalveolar vertical dimension measured the perpendicular distance from the tip of the lower incisor to the mandibular plane [see Figures 13(a)(b) and (c)].

At both the pre- and post-treatment stages (Times 1 and 2), the thumbsucking group had a significantly shorter vertical measurement from the tip of the lower incisor to the mandibular plane than did the contol group [see Figures 13(a) and (b)]. Only those in the ten-year-old age category at Time 2 were within the 0.95 confidence interval.

The long-term stage (Time 3) showed that for the twelve-, thirteen- and fourteen-year-old age categories, the study sample was well within the normal range. Once again, the ten-, fifteen- and sixteen-year-old age categories had a much shorter vertical dimension from the incisal edge of the lower incisor to the mandibular plane.

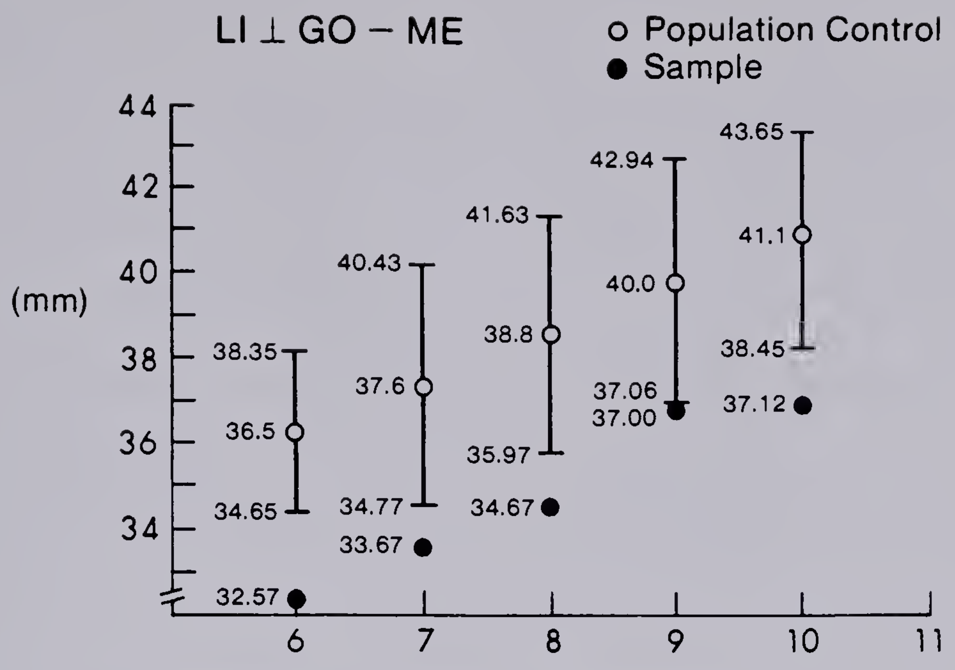


Figure 13a Time 1 (pre-treatment)

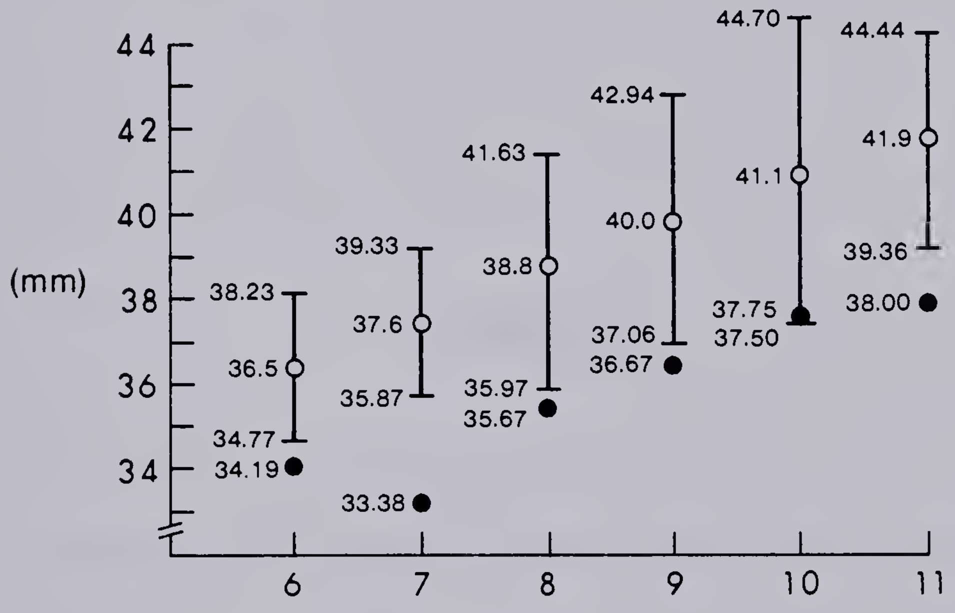


Figure 13b Time 2 (post-treatment)

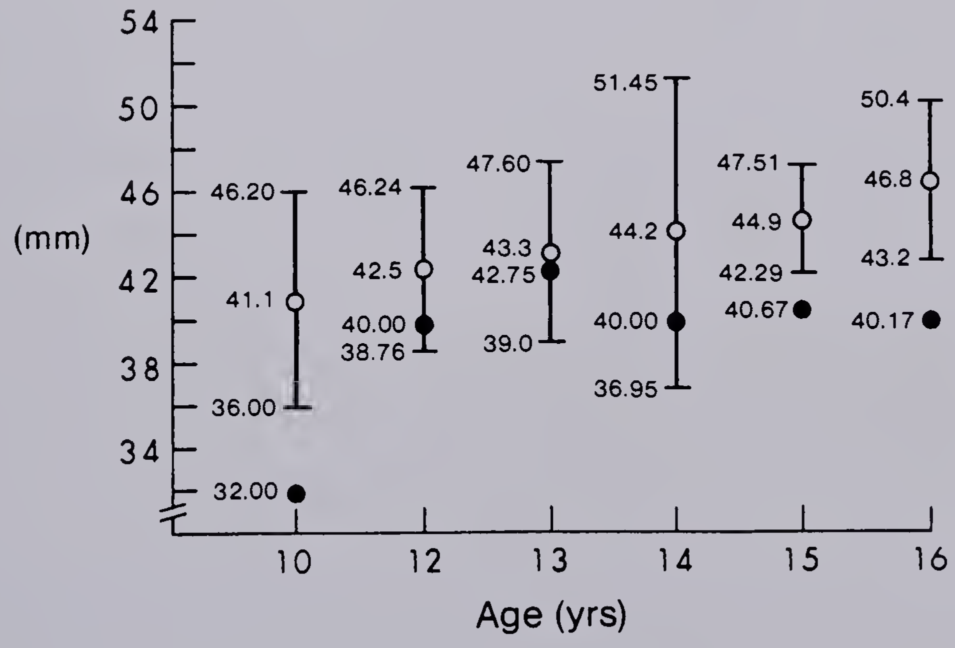


Figure 13c Time 3 (long-term)

CHAPTER 5

DISCUSSION

5.0 Discussion

The patient sample for this study consisted of 33 Edmonton school children who had participated in earlier studies designed to evaluate the effectiveness of various methods to arrest chronic thumbsucking habits. The first of these studies (Haryett *et al.*, 1967) selected children who were persistent thumbsuckers and who were all over four years of age. All of the patients in this original study had records taken before any treatment was initiated. Each of the 33 children had worn a crib from three months to one year depending upon the child's original treatment category. Regardless of the length of time the appliance was worn, records were taken one year after the pre-treatment records were made.

In 1976, Lamont was able to obtain a third set of records for these patients. He studied the dental changes that occurred between younger and older children and found that the age at which thumbsucking ceased did not affect the eventual position of the anterior teeth. He made inferences in his thesis that there were possibly some skeletal changes, particularly regarding the upper and lower anterior facial dimensions, that may have been effected in children with persistent thumbsucking habits. It was because of those inferences made by Lamont (1976) that the author was led to further study the linear vertical dimensions in those children who had had their thumbsucking habit arrested with the use of a crib.

The cephalometric radiographs of the 33 patients pre-treatment, post-treatment, and long-term were studied to determine what skeletal and dentoalveolar changes occurred. These were compared to the "Michigan" control sample (Riolo *et al.*, 1974) to determine if changes were significant over a long period of time. In order to assess the skeletal and dentoalveolar changes in the vertical dimension, eleven variables were used to express these vertical associations (Biggerstaff *et al.*, 1977). The average skeletal and dentoalveolar changes that took place during the course of the present study are listed in Table 6.

Although some of these variables have been described by different authors as factors related to open and deep overbites, the trends expressed between these studies seem to be consistent.

Table VI

Mean Values of Cephalometric Linear Measurements for the Entire Sample for the Three Observation Periods

Cephalometric Measurement (mm)	Observation Period Pre-treatment	 Post-treatment	 Long-Term
Skeletal			
SE–ANS–PNS	40.60	40.60	47.63
N–ME	96.93	103.28	119.05
N–ANS	44.98	45.67	55.05
ANS–ME	59.28	59.55	66.17
S–GO	62.08	62.56	75.05
AR–GO	37.23	37.93	45.57
S–AR	29.00	29.78	34.17
Dentoalveolar			
UM ⊥ ANS–PNS	17.53	17.81	22.38
UI ⊥ ANS–PNS	23.25	24.07	29.05
LM ⊥ GO–ME	26.98	27.10	30.52
LI ⊥ GO–ME	34.63	34.19	40.21

5.1 Linear skeletal measurements

5.1.1 Anterior face height

In the past, vertical dimensions of the face were often described in terms of the upper face height (UFH) in relation to the lower face height (LFH). Although the particular reference points by different authors varied, the basic conclusions reached were much the same. The influence that thumbsucking has on these skeletal structures of the face has long been debated. In 1938, Swinehart felt that thumbsucking inhibited the normal vertical growth of the maxilla whereas Taft (1966), who studied 35 children who were prolonged thumbsuckers, concluded that changes to the maxilla and dentition were not significant but that mandibular position was affected (Bjork, 1963, 1969; Schudy, 1965; Isaacson *et al.*, 1971; Gasson and Lavergne, 1977).

Moore (1970) studied monkeys with persistent thumbsucking habits and concluded that the force of the thumb inhibited the normal vertical growth in the maxilla. According to Lamont (1976), who compared children who had stopped thumbsucking earlier in comparison to those who had stopped later, noted that the group that stopped thumbsucking earlier had a greater upper face height dimension than the group of children who stopped thumbsucking at an older age when observed at the long-term observation period.

In a cephalometric analysis proposed by Wylie and Johnson (1952), the vertical proportions of the normal face were measured along the line nasion–menton. The anterior nasal spine (ANS) served as the point of separation between the upper and lower face. The ratio of the upper face height to total face height (UFH/TFH) was reported as 43.6% for males and 43.2% for females.

According to Strang and Thompson (1958), the upper face height (N–ANS) should be 45% of the total face height (N–ME), while the lower facial height should be 55%, in a normal harmonious face. These values were close to the values stressed by Wylie (1944)(ANS–ME, 46.6%) and Schudy (1964)(ANS–ME, 56.5%).

Horowitz and Thompson (1967) compared a group of normal untreated post-adolescent females and males. They measured face height, upper face height, and lower face height along the nasion-gnathion line. They found that the dimensions obtained for males were generally larger than those for females. The control sample from Michigan which was used in the present study also showed that the females had mean values significantly less than those of males (see Appendix I). The results of the present study tend to verify this point. Although the present study was not separated into males and females because of the smallness of the sample, the predominance of the 33 patients were females (25 of 33). At Time 3 (long-term), it was noted that the anterior face height was significantly less than the control at the fifteen- and sixteen-year-old age categories (see Figures 4,5,6). Since twelve out of the fifteen patients in these two age categories were females, the author felt that the general drop in mean measurements at these ages were due primarily to sex. A much larger sample of both males and females would be necessary in order to verify the present results.

In 1971, Nahoum studied the lateral cephalometric radiographs of 52 open-bite cases ranging in age from ten to 24 years. These open-bites were compared with a sample of 166 subjects (92 males and 74 females) from a group of young adults with acceptable untreated Class I occlusions. Unlike the study by Wylie and Johnson (1952), he used the UFH/LFH ratio instead of the UFH/TFH ratio. He felt this was necessary in order to avoid the error of using one of the measurements twice. It was imperative according to Nahoum that in calculating ratios, the two variables be distinct from one another.

Most investigators agree that the total anterior face height is greater in open-bite patients (Wylie and Johnson, 1952; Praskash and Margolis, 1952; Hapak, 1964; Bjork, 1963, 1969; Horowitz and Thompson, 1967; Subtelny and Sakuda, 1964; Creekmore, 1967; Nahoum, 1971; Schendel *et al.,* 1976; Opdebeeck et al., 1978).

Hapak (1964) and Schudy (1964), in separate studies, compared vertical dysplasia patients with controls and both found that the upper face heights (N–ANS) tended to be the same in both groups. Schudy studied 270 patients with malocclusions and

compared them with a group of control patients between ten and fourteen years of age. He measured facial divergence by the SN–MP angle. He found that there was a positive correlation between facial height and the SN–MP angle and the OP–MP angle. The author's clinical impression tends to support the results of Hapak (1964) and Schudy (1964).

In 1969, Richardson reported that the differences between means for upper face height in his paired study of open-bite and closed-bite subjects were very small. In the present study, the linear vertical measurements for the upper anterior face height were slightly less overall than the normal control group both at the pre- and post-treatment stages but at the long-term phase (between ten and sixteen years), they were relatively normal. One might ask, why was there such a change between Times 1 and 2? One thing that none of the cited studies have done is to study children at an earlier age as was done in the present study. Most of the studies comparing patients with vertical skeletal problems have been compared to controls between the ages of ten and approximately twenty years. This would fall within the third observation period of the present study. A number of possible factors could be involved which could contribute to demonstrating significant changes at Times 1 and 2. At Time 1, the patients in the present study were relatively young (mean age 6.48 years) and were therefore actively growing individuals. In the craniofacial complex at this time, there is considerable sutural and nasal septal growth which carries the nasomaxillary complex in a downward and forward direction (Enlow, 1965, 1966). The present study sample were predominantly females and therefore had smaller overall faces which, due to sexual dimorphism, could possibly result in smaller measurements. The control sample to which this sample was compared was not a local one because at the present time the University of Alberta does not have such a control sample. There may have been inherent differences between the study sample and the "Michigan" control. The children in the present study initially had been persistent thumbsuckers. The habit had been arrested whether by the use of a crib and/or a combination of a crib and psychological motivation. This may have allowed the dentofacial complex in the upper facial region to develop in a more normal growth pattern. Further studies would be necessary to determine if non-treated persistent

thumbsuckers behaved in a similar manner over a prolonged period of time.

Richardson (1969) constructed a facial polygon to measure absolute linear and angular values in three age groups. He reported that the total face height (N–ME) was larger in open-bite patients than in closed-bite patients and that the increase in total face height in open-bite cases was largely the result of an increase in the lower face height. He found that the lower face height measurement was closely correlated with all other linear measurements in the facial polygon. He also observed like Bjork (1953), that the changes were secondary to changes in the craniofacial skeleton. Bjork (1962, 1963, 1969), and Lavergne and Gasson (1977), in studies using metallic implants, have clearly demonstrated that variations in growth do occur between facial regions and that such variations do produce rotations of the mandible in either a forward or backward direction. Bjork (1969) further demonstrated that the apparent constancy of downward and forward facial growth was a result of rotations combined with remodelling. Brodie, in 1953, found that during growth, a number of patients did not maintain the proportions of their initial facial pattern.

The present study showed that the total anterior face height was significantly shorter than the control group at the pre- and post-treatment stages but was within the range of normal at the twelve-, thirteen- and fourteen-year-old age categories at Time 3. Because the study sample was not divided into open- and closed-bite categories, the sample could not therefore be adequately compared to earlier studies by Hapak (1964), Schudy (1964), and Richardson (1969). It is interesting to note, however, that the total anterior face height, upper anterior face height, and lower anterior face height all tended to follow a very similar pattern suggesting to the author that the particular growth pattern of these individuals in the anterior facial complex were relatively constant.

Nahoum (1971) felt that the contribution of the palatal plane to the anterior face height ratio should be emphasized more in studies dealing with open-bite. The importance of this plane becomes apparent when one considers the fact that the palate separates the nasal and oral spaces. These spaces are two adjacent, functionally related but independent functional matrices. It is possible, then, that the development of the spatial volumes

of the oral and nasal cavities has an etiologic effect on the development of open-bite and longer total anterior face heights (Moss, 1960, 1968, 1969). Since the effect of chronic thumbsucking on the dentofacial structures has been shown to be detrimental (Swinehart, 1938; Sillman, 1951; Klein, 1952; Bowden, 1966), the position of the anterior nasal spine and that of the palatal plane may be such that the distance from nasion to anterior nasal spine would be less in thumbsucking cases. The fact that the mean pre-treatment age of the present sample was 6.48 years suggests that many of the permanent central incisors of these patients would not have erupted fully. This could also contribute to shorter vertical measurements at the pre-treatment stage for both the overall and lower anterior facial height dimensions.

5.1.2 Posterior face height

The behavior of the posterior face height (PFH) over the three observation periods is shown in Table 6. Figure 9 revealed that the upper posterior face height (S–AR) of the thumbsucking group was not significantly different from that of the normal control group. This pattern tended to maintain itself throughout all of the three observation periods. This could possibly indicate that thumbsucking did not have any significant effect on the upper posterior face height.

The relationship of the vertical distance from the spheno-ethmoid registration point to the palatal plane (SE ⊥ ANS–PNS) reflects the sutural as well as the nasal septal growth in the upper posterior facial region. Figure 3 indicates that prior to the commencement of treatment, the thumbsucking sample had a significantly shorter vertical distance than that of the control group. In the year between pre- and post-treatment, very little change was observed, however, from Time 2 to Time 3, there appeared to be a trend towards the normal group except at ages fifteen and sixteen years.

The difference between the results of these two variables (S–AR, SE ⊥ ANS–PNS), is the fact that the upper posterior face height (S–AR) reflects growth of the cranial base. According to Bjork (1955), Koski (1960), and Lewis and Roche (1974),

growth of the cranial base is completed between six and eight years of age. The present study confirmed this finding. Since the variable SE ⊥ ANS–PNS reflects an actively growing area of the upper posterior facial region, we see the same general pattern over the three time periods as has been noted in the previous linear vertical measurements.

In 1976, Schendel *et al.* studied 31 white patients between the ages of seventeen and 25 years with vertical maxillary excess or long face syndrome (LFS). They measured a number of angular and linear cephalometric measurements. One-half of these patients had anterior open-bites and the other half had overbites. The differences in the posterior face height (S–GO) measurements were significant. They found that the average posterior face height or the open-bite group was smaller (72.87mm) compared to the posterior face height of the overbite group (80.13mm). This was correlated with a shortened ramus height of the open-bite group (54.53mm) while the ramus height of the non open-bite group was 60.88mm compared to the normal of 56.30mm. Their data suggested that there was greater vertical growth in the ascending mandibular ramus of the non open-bite group which prevented the development of an open-bite (Subtelny and Sakuda, 1964; Richardson, 1969; Isaacson *et al.*, 1971; Nahoum *et al.*, 1972). Schendel *et al.* (1976) also noted that the upper posterior face height (S–AR) was not significantly different in both the open-bite and non open-bite groups. They observed that the lower posterior face height was largely controlled by the length of the mandibular ramus (Bjork, 1963, 1969; Subtelny and Sakuda, 1964; Richardson, 1969; Isaacson *et al.*, 1971; Opdebeeck *et al.*, 1978). It must be remembered however, that there are a multitude of other factors involved other than the ones just discussed. For example, Droel and Isaacson (1972) felt that the posterior face height was also influenced by the vertical and horizontal position of the glenoid fossa.

Opdebeeck *et al.* (1978) recently studied the two extremes of vertical dysplasia which they described as the long face syndrome (LFS) and the short face syndrome (SFS). They found similar results as Schendel *et al.* had observed in 1976 that there was a reduced posterior face height (S–GO) in the LFS as compared to the SFS. They also observed that the upper posterior face height (S–AR) was not significantly different in either

group.

The present study showed a number of similar results even though the study sample was comprised of persistent thumbsuckers and could not directly be compared to those of Schendel *et al.* (1976) or Opdebeeck *et al.* (1978). The subjects in the present study were considerably younger and would therefore have had smaller faces overall. Like Schendel *et al.* (1976) and Opdebeeck *et al.* (1978), the present study showed that the upper posterior face height remains quite stable regardless of the vertical skeletal discrepancy again suggesting that persistent thumbsucking doesn't have a significant effect on the upper posterior face height measurement. The present study showed that the posterior face height (S–GO) was significantly different from the control group at Times 1 and 2. This would be expected since these patients were much younger and therefore would still have a considerable amount of mandibular growth left. Only at the sixteen-year-old category at Time 3 was the study sample significantly different from that of the control group.

5.2 Dentoalveolar measurements

5.2.1 Posterior dentoalveolar measurements

Bjork (1963) studied the variations in the growth pattern of the human mandible using the implant method. He felt that growth of the mandible was the most important factor in establishing facial height. He noted that the downward growth of the upper first molar exceeded the downward growth of the upper incisor by a two-to-one ratio. Merow (1962) found a correlation coefficient of 0.80 with this growth and increase in the facial height. In 1967 Creekmore found this correlation to be 0.62 which was significant at the 0.1 level. He noted that about 70% of the total vertical growth of the face was accounted for by the downward growth of the maxillary molar teeth leaving some 30% to the growth of the lower first molar.

Bjork and Skieller (1972) and Lavergne and Gasson (1977) noted that the maxilla changed in relation to the cranial base and that the growth rotations of the maxilla combined with alveolar growth of the maxillary molars, were reflected in changes of mandi-

bular position (Schudy, 1965, 1966, 1968). The present study showed that the posterior maxillary dentoalveolar height was not significantly different from the control group at all three observation time periods except at the six-year-old age category. It should be noted that in some cases, if the six-year molars were not present clinically or on the models, that measurement was omitted in the initial stage. This would therefore have an effect on the vertical skeletal measurement for that variable.

Schendel *et al.* (1976) studied varieties of cases with vertical maxillary excess (long face syndrome). In comparing 31 patients to the control of Isaacson *et al.* (1971), they noted that the posterior height of the maxilla, as measured from the mesial cusp tip of the first molar to palatal plane, was greater than in the normal group. Opdebeeck *et al.* (1978) found much the same results. Isaacson *et al.* (1971) studied skeletal and dental factors associated with vertical facial growth and found a strong correlation between the vertical height of the upper molar to that of the SN–MP angle.

The mandibular molar dentoalveolar height measurement was represented by the variable "lower molar perpendicular to mandibular plane" (LM ⊥ GO–ME). Schudy (1968) felt that the vertical growth of the mandibular molar teeth played a minor role in establishing facial height. He did conclude however, that during active orthodontic treatment it was a major factor in the establishment of a proper overbite relationship. He also felt that in growing individuals that the mandibular molar dentoalveolar height accounted for about 30% of the total vertical growth at the anteroposterior level of the first permanent molar teeth.

In 1971, Isaacson *et al.* found that in both low and average mandibular plane groups, the mean mandibular height in the first molar area was essentially the same. In high mandibular plane cases however, he found that the mean mandibular molar height was increased by approximately 3mm over the other group. This confirms the earlier study by Schudy (1968) that although mandibular molar height does contribute to an increased vertical development of high angle cases, it is relatively less contributory than the posterior maxillary vertical development.

Opdebeeck *et al.* (1978) found that the posterior mandibular molar height was shorter in deep bite cases than in open-bite cases. In the present study, there was not an equal distribution of males and females. Because there were predominantly more females to males (25 to eight), the mean vertical measurements would possibly be less as shown by Isaacson *et al.* (1971) and Riolo *et al.* (1974) (see Appendix I). All of the studies previously referred to have been on older children which would correspond closer to those of the present study at Time 3 (long-term). Those in the present study were much closer to the normals at long-term than at the earlier observation periods.

Subtelny and Sakuda (1964) studied 25 open-bite cases and compared them to thirty cases of normal occlusion. This group was made up of patients over twelve years of age. They noted that the mandibular molar dentoalveolar height was the same in both of the groups. The present study, although started out at a much earlier age, found that at the long-term stage the results were similar. The twelve-, thirteen- and fourteen-year-olds in the present study were comparable to the control group. A question that has arisen from the present study by the author is what effect has long-term crib and/or holding arch therapy had on the vertical eruption of upper and lower molars? Further studies would be necessary to investigate this topic.

5.2.2 Anterior dentoalveolar measurements

The relationship of the upper and lower anterior dentoalveolar measurement to the overall face height is also very important. Subtelny and Sakuda (1964) noted that there was a significantly greater eruption of the maxillary incisors in open-bite cases. Isaacson *et al.* (1971) noted the interrelationship between the MP–SN angles and the amount of vertical alveolar growth. High MP–SN angle cases had a tendency toward open-bite and showed that the maxillary and mandibular anterior dentoalveolar heights were greater [Schendel *et al.*, (1976)].

The maxillary incisor teeth move downward and away from the anterior nasal spine by the growth of the alveolar processes. The increment of growth, according to

Schudy (1968), is about one-third that of the mandibular incisors. He felt that between eleven and fourteen years of age, the maxillary incisors do not move away from ANS to any significant degree, while during this same period, the maxillary molars usually grow 2mm to 5mm. This particular phenomenon could possibly account for the fact that the occlusal plane descends more at the posterior end than at the anterior end. In 1971, Nahoum studied open-bite cases and compared them to normals. He felt that more consideration should be given to the cant of the palatal plane. The importance of the palatal plane becomes apparent when one considers that the anterior nasal spine is used as the point which divides the anterior face into upper and lower positions. Another important consideration is the fact that the skeletal tissues respond to the demands of the soft tissues and other factors and that the cephalometric radiographs merely convey the effects of these functions (Moss, 1960, 1968, 1969). Since it is generally accepted that persistent thumbsucking affects the dentition in varying degrees (Swinehart, 1938; Sillman, 1951; Bowden, 1966), depending upon the frequency and intensity, the cant of the palatal plane could therefore be affected.

The small amount of growth of the upper incisors helps to prevent excessive overbite in many instances. Contrary to what one might expect to find, the upper incisors usually grow much more in open-bite cases than in closed-bite cases (Subtelny and Sakuda, 1964; Isaacson *et al.*, 1971; Schendel *et al.*, 1976). The present study, although not divided into open- and closed-bite cases, showed some interesting trends. The study sample was significantly different from the control group at the pre- and post-treatment observation periods. Once again, this would be expected since these patients were younger, predominantly female and actively growing. In the pre-treatment stage, many of the patients were still in the deciduous dentition stage and therefore the anterior upper dentoalveolar height would be shorter. The effect of the crib therapy from Time 1 to Time 2 did not seem to have any effect on the measurement significantly (see Figure 11). At the fifteen- and sixteen-year-old age categories (Time 3), the study sample showed shorter measurements for this variable. Of the fifteen subjects that were in these two age categories, twelve of them were females which could possibly account for the shorter linear measurements.

The mandibular incisal growth according to Schudy (1968) is perhaps the greatest and most variable of all the dentoalveolar components of growth. It seems that the mandibular incisor is the great "compensator" in preventing open-bites. In the present study, the lower anterior dentoalveolar height (LI ⊥ GO–ME) followed the same general trend over the three observation time periods as that of the upper anterior dentoalveolar height (UI ⊥ ANS–PNS).

It is important to realize that other influences such as environmental factors play a major role in effecting growth and development of the dentofacial complex. Such influences as muscles of mastication, lips, and tongue can influence the positioning of upper and especially lower incisors (Moss, 1964).

It would appear from the discussion, that there is a great deal of variability in the amounts of growth increments in the various vertical dimensions and to understand the cause and effect relationship among these different growth entities, a more in-depth study into growth and development would be necessary.

In general, there appears to be a uniformity of orthodontic opinion that the skeletal and dentoalveolar factors associated with vertical skeletal dysplasias are still not fully understood. This may be partly attributable to differences of age and sex as well as the sample investigated and partly to the possibility that the manifestations of vertical skeletal problems are not uniform in respect to etiological factors. In recent years, oral surgeons such as Schendel *et al.* (1976) and Opdebeeck *et al.* (1978) have made great strides to improve surgical techniques to reduce severe vertical discrepancies. The author feels, based on the current literature, that in cases of severe vertical dysplasias such as open- and closed-bite cases, the following linear measurements should be utilized:

(a) anterior face height (N–ME)

(b) upper anterior face height (N–ANS)

(c) lower anterior face height (ANS–ME)

(d) posterior face height (S–GO)

(e) upper posterior face height (S–AR)

(f) lower posterior face height (AR–GO)

(g) upper posterior dentoalveolar height (UM ⊥ ANS–PNS)

(h) lower posterior dentoalveolar height (LM ⊥ GO–ME)

(i) upper anterior dentoalveolar height (UI ⊥ ANS–PNS)

(j) lower anterior dentoalveolar height (LI ⊥ GO–ME)

Even with all of the abnormal skeletal manifestations present in many individuals, the human body is the "master" in providing necessary compensation in growth and function. It is worth remembering that the normal range of skeletal and dentoalveolar morphology is quite extensive, so that although some of the samples which have been used in studies are big enough to satisfy the arbitrary requirement for a large sample, they may not have been numerically strong enough to raise some differences to the level of statistical significance.

It is quite apparent from the present study that an attempt to determine the vertical skeletal changes of a group of arrested thumbsuckers was a more monumental task than it appeared at the onset. The present study was useful to help appreciate the wide range of variability associated with individuals. It is only through continued longitudinal growth studies that the investigator can more fully appreciate the wide variation of individual growth responses to similar environmental conditions.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.0 Summary and Conclusions

The purpose of this study was to utilize vertical cephalometric measurements on lateral headfilms of the craniofacial complex to determine if children with arrested thumbsucking habits had altered to a significant degree their basic vertical facial growth pattern. The lateral cephalometric radiographs of 33 patients (25 females and 8 males) from an earlier study were analyzed using linear measurements from serial radiographs at three times (pre-treatment, post-treatment, and long-term). Initially, the patients were grouped according to their type of growth pattern (horizontal, vertical, and horizontal-vertical) based on the steepness of the SN–MP angle. Seven skeletal and four dentoalveolar linear measurements were made for each patient at each of the three different time periods. Means and standard deviations were calculated for each variable. These vertical dimensions were analyzed using the age- and sex-related University of Michigan mean values for comparative data for each measurement. Confidence intervals were established for each variable at the 0.95 level for the three different stages of observation and the sample study was compared to them. The following conclusions were drawn:

6.1 There appeared to be significant differences (0.05 level) at the pre-treatment age for each of the skeletal and dentoalveolar variables except for:

(a) Upper posterior face height (S–AR)
(b) Upper molar perpendicular to the palatal plane (UM ⊥ ANS–PNS)

6.2 At the long-term observation period (Time 3), for each of the skeletal and dentoalveolar variables, there did not appear to be a significant difference between the study sample and that of the control group.

6.3 Sutural growth of the maxillary posterior face height (SE–ANS–PNS) was significantly less in the persistent thumbsucking group prior to crib therapy than that of the control. At Time 3, there was a tendency for the study sample to be like that of the control group.

6.4 The total anterior face height of the thumbsucking group was significantly less than that of the normals prior to the commencement of crib therapy. This did not change significantly during the one year following but were within the range of normal at the long-term stage.

6.5 The upper and lower anterior face height, although being significantly different from the control group at pre-treatment (0.05 level) were well within the normal confidence interval at long term.

6.6 The upper anterior face height increased more over the three observation time periods than that of the lower anterior face height by 3.18 mm.

6.7 The total posterior face heights of the study sample were significantly shorter (0.05 level) than the control group at pre-treatment but were within the normal limits at long term.

6.8 The upper and lower posterior face heights were somewhat different. Unlike the lower face height, the upper posterior face height for the study sample was not significantly different at any of the three times. The lower posterior face height however was significantly different at pre-treatment for most of the age categories but was much like the control group at the long-term observation period.

6.9 The mean vertical dentoalveolar heights of the maxillary and mandibular molars showed differences. In general, the upper molar dentoalveolar height (UM ⊥ ANS–PNS) was not significantly different from the control group over the three time periods. The lower molar perpendicular to the mandibular plane (LM ⊥ GO–ME) did however show more variation. This variable in general showed a significant difference at Time 1 but was more like the control group at Time 3.

6.10 The mean vertical dentoalveolar heights of the maxillary and mandibular incisors showed much the same pattern over the three time periods. Prior to crib therapy (pre-

treatment) and again at the post-treatment stage, there appeared to be a significant difference between the two groups with that of the control group. The long-term stage showed no significant difference between the vertical dentoalveolar heights of the upper and lower incisors with that of the control group.

6.11 This study may suggest that arresting the persistent thumbsucking habit is important to allow a more normal pattern of growth to occur over a prolonged period of time.

CHAPTER 7

BIBLIOGRAPHY

BIBLIOGRAPHY

Ambler, H. L. Thumb-sucking. *Dent. Digest.,* 10:1116—1118, 1904.

Anderson, D. L., Thompson, G. W. and Popovich, F. Relation of socioeconomic level to sucking habits and tooth eruption. *Am. J. Orthod.,* 63:432 (abst.), 1973.

Andrews, L. F. The six keys to normal occlusion. *Am. J. Orthod.,* 62:296—309, 1972.

Angle, E. H. Classification of malocclusion. *Dental Cosmos,* 41:248—264, 1899.

Baalak, J. and Frisk, A. Finger sucking in children; a study in incidence and occlusal condition. *Acta Odont. Scan.* 29:499—512, 1971.

Backlund, E. Facial growth and the significance of oral habits, mouthbreathing and soft tissues for malocclusion. *Acta Odont. Scand.* 21 (Sippl. 36), 1963.

Bambha, J. K. Longitudinal cephalometric roentgenographic study of face and cranium in relation to body height. *J. Am. Dent. Assoc.,* 63:788—799, 1961.

Baril, C. and Moyers, R. E. An electromyographic analysis of the temporalis muscles and certain facial muscles in thumb and finger sucking patients. *J. Dent. Research.,* 39:536—553, 1960.

Baum, A. T. A cephalometric evaluation of the normal skeletal and dental pattern of children with excellent occlusions. *Angle Orthod.,* 21:96—103, 1951.

Biggerstaff, R., Allen, R. C., Tuncay, O. C. and Berkowitz, J. A vertical cephalometric analysis of the human cranial facial complex. *Am. J. Orthod.,* 72:397—405, 1977.

Bjork, A. *The face in profile.* Svensk. Tandl. Tidskr. 40:56, 1947.

Bjork, A. Some biological aspects of prognathism and occlusion of the teeth. *Acta Odont. Scand.* 9:1—40, 1950.

Bjork, A. Variability and age changes in overjet and overbite. *Am. J. Orthod.,* 39:799—801, 1953.

Bjork, A. Facial growth in man, studied with the aid of metallic implants. *Acta Odont. Scand.,* 13:9—34, 1955.

Bjork, A. Cranial base development. *Am. J. Orthod.,* 41:198—225, 1955.

Bjork, A. A roentoenographic cephalometric growth analysis. In Pruzansky, S. (editor): *Congenital anomalies of the face and associated structures.* Springfield, Ill.: Charles C. Thomas, 237—250, 1961.

Bjork, A. Facial growth in bilateral hypoplasia of the mandibular condyle; a radiographic, cephalometric study of a case, using metallic implants, *Vistas in Orthodontics,* edited by B. Kraus and R. Reidel; Lea and Febiger, 349—358, 1962.

Bjork, A. Variations in the growth pattern of the human mandible: longitudinal radiographic study by the implant method. *J. Dent. Res.,* 42:400—411, 1963.

Bjork, A. Prediction of mandibular growth rotation. *Am. J. Orthod.,* 55:585—599, 1969.

Bjork, A. and Skieller, V. Facial development and tooth eruption. An implant study at the age of puberty. *Am. J. Orthod.,* 62:339—383, 1972.

Bonwell, T. *The dentition and palate of the Australian Aboriginal.* T. D. Campbell, editor, Hassell Press, Adelaide, 1925.

Bowden, B. D. Thumbsucking effects of digital and dummysucking on archwidth, overbite, and overjet. *Aust. Dent. J.,* 11:396—404, 1966.

Bowden, A. Effects of digit sucking and use of pacifier. *Dent. abstr.,* 12:427, 1967.

Broadbent, B. H. A new X-ray technique and its application to orthodontia. *Angle Orthod.,* 1:45—66, 1931.

Broadbent, B. H. The face of the normal child. *Angle Orthod.,* 7:183—208, 1937.

Broadbent, B. H. Sr., Broadbent, B. H. Jr. and Golden. W. H. *Bolton Standards of Dentofacial Developmental Growth.* St. Louis: C. V. Mosby Co., 1975.

Brodie, A. G. On the growth pattern of the human head from the third month to the eighth year of life. *Am. J. Orthod.,* 68:209—262, 1941.

Brodie, A. G. On the growth of the jaws and the eruption of the teeth. *Angle Orthod.,* 12:109—123, 1942.

Brodie, A. G. Facial patterns—A theme on variation. *Angle Orthod.,* 16:75—88, 1946.

Brodie, A. G. Late growth changes in the human face. *Angle Orthod.,* 23:146—157,1953.

Brodie, A. Research in the department of orthodontic graduate college, University of Illinois, from 1951 to 1955, *Angle Orthod.,* 27:212—215, 1957.

Bushra, F. Variation in the human facial pattern in norma lateralis. *Angle Orthod.,* 8:100—102, 1948.

Case, C. S. *A practical treatise on the technique and principle of dental orthopedia and prosthetic correction of cleft palate.* Chicago: C. S. Case Co., 1921.

Coben, S. E. The interaction of facial skeletal variants. *Am. J. Orthod.,* 41:409—434, 1955.

Creekmore, T. Inhibition or stimulation of the vertical growth of the facial complex, its significance to treatment. *Angle Orthod.,* 37:285—297, 1967.

Davenport, C. B. Postnatal development of the head. *Proc. Am. Phil. Soc.,* 83:1—26, 1940.

Davidson, P. O., Haryett, R. D., Sandilands, M. and Hansen, F. C. Thumbsucking: habit or symptom? *J. Dent. Child.,* 33:252—259, 1967.

Diamond, M. The ramus as a factor in the development of the dental height. *J. Dent. Res.,* 22:346—347, 1943.

Diamond, M. The development of dental height. *Am. J. Orthod.,* 30:589—605, 1944.

Downs, W. B. Variation in facial relationships: their significance in treatment and prognosis. *Am. J. Orthod.,* 34:812—840, 1948.

Droel, R. and Isaacson, R. J. Some relationships between the glenoid fossa position and various skeletal discrepancies. *Am. J. Orthod.,* 61:64—78, 1972.

Enlow, D. H. A study of postnatal growth and remodeling of bone. *Am. J. Anat.,* 110:79—102, 1962.

Enlow, D. H. and Harris, D. B. A study of the postnatal growth of the human mandible. *Am. J. Orthod.,* 50:25—50, 1964.

Enlow, D. H. and Bank, S. Growth and remodeling of the human maxilla. *Am. J. Orthod.,* 51:446—464, 1965.

Enlow, D. H. A morphogenetic analysis of facial growth. *Am. J. Orthod.,* 52:283—299, 1966.

Enlow, D. H. Wolff's law and the factor of architectomic circumstance. *Am. J. Orthod.,* 54:803—822, 1968.

Enlow, D. H. *Handbook of facial growth.* Toronto: W. B. Saunders Co., 1975.

Fleming, H. B. An investigation of the vertical overbite during the eruption of the permanent dentition. *Angle Orthod.,* 31:53—62, 1961.

Gale, E. Thumbsucking reconsidered. *Am. J. Orthod.,* 55:167—170, 1969.

Gardiner, J. H. A survey of malocclusions and some etiological factors in 1000 Sheffield schoolchildren. *Dent. Pract.,* 6:187—198, 1956.

Gasson, N. and Lavergne, J. The maxillary rotation: Its relation to the cranial base and the mandibular corpus, An implant study. *Acta Odont. Scand.,* 35:89—94, 1977.

Goldsman, S. The variation in skeletal and dental pattern in excellent adult facial types. *Angle Orthod.,* 29:63—92, 1959.

Goldstein, M. Changes in dimensions and form of the face and head with age. *Am. J. Phys. Anthropol.,* 22:37—89, 1936.

Graber, T. M. Extrinsic factors. *Am. J. Orthod.,* 44:26—45, 1958.

Graber, T. M. The finger-sucking habit and associated problems. *J. Dent. Child.,* 25:145—151, 1958.

Graber, T. M. *Orthodontics; principles and practice.* Edition II. Philadelphia: W. B. Saunders Co., Chapter 6, 296—298, 1972.

Gregory, W. K. *Our face from fish to man.* New York: G. P. Putman's Sons, 1929.

Hapak, F. Cephalometric appraisal of the open-bite case. *Angle Orthod.,* 34:65—72, 1964.

Haryett, R. D., Hansen, F. C. and Davidson, P. O. Chronic thumbsucking. *Am. J. Orthod.,* 57:164—178, 1970.

Hellman, M. Changes in the human face brought about by development. *Internat. J. Orthod.,* 13: 475—516, 1927.

Hellman, M. Open-bite. *Int. J. Orthod.,* 17:421—444, 1931.

Hellman, M. Introduction to growth of the human face from infancy to adulthood. *Internat. J. Orthod.,* 18:777—798, 1932.

Hellman, M. The face in its developmental career. *Dental Cosmos* 77:685—787, 1935.

Hellman, M. Some biologic aspects; their implications and application in orthodontic practice. *Internat. J. Orthod.,* 23:761—785, 1937.

Hofrath, H. Die Bedeutung der Rontgenfern-used Abstandsaufrahman fur die Daignostik der Kieferanamalien. *Fortschr. Orthod.,* 1:232, 1931.

Hopkin, G. B. Houston, W. J. B. and James, G. A.: The cranial base as an etiological factor in malocclusion. *Angle Orthod.,* 38:250—255, 1968.

Horowitz, S. L. and Thompson, R. H. Variation of the craniofacial skeleton in post-adolescent males and females. *Angle Orthod.,* 34:97—122, 1967.

Hughes, B. O. The growth of children—psychological and hereditary factors. *Am. J. Orthod.,* 35: 21—23, 1949.

Isaacson, K. G. Overbite and facial height. *Dent. Pract.* (Bristol), 20:298—408, 1970.

Isaacson, J. R. Isaacson, R. J., Speidel, T. M. and Worms, F. W. Extreme variation in the vertical facial growth and associated variation in skeletal and dental relations. *Angle Orthod.,* 61:219—229, 1971.

Jensen, E. and Palling, M. The gonial angle. *Am. J. Orthod.,* 40:120—133, 1954.

Johnson, L. R. The status of thumbsucking and fingersucking. *J. Am. Dent. Assoc.,* 26:1245—1254, 1939.

Johnson, E. The frankfort-mandibular plane angle and the facial pattern. *Am. J. Orthod.,* 36:516—533, 1950.

Jones, B. H. and Meredith, H. V. Vertical changes in osseous and odontic positions of the human face height between ages of 5 and 15 years. *Am. J. Orthod.,* 52:902—921, 1966.

Kantorowicz, A. and Korkhaus, G. The self correction of orthodontic anomalies. *Tr. First Internat. Orthodontic Congress.* p. 40—65, 1926.

King, E. W. Cervical anchorage in Class II division 2 treatment, A cephalometric appraisal. *Angle Orthod.,* 27:98—103, 1957.

Klein, E. Pressure habits, etiological factors in malocclusion. *Am. J. Orthod.,* 38:569—587, 1952.

Koski, K. Some aspects of the growth of the cranial base and the upper face. *Odont. Tidski.* 68:344—358, 1960.

Koski, K. The Finnish female face in norma lateralis. *Trans. Europ. Orthod. Soc.*, 463—469, 1964.

Koski, K. Cranial growth centres: facts or fallacies? *Am. J. Orthod.*, 54:566—583, 1968.

Krogman, W. M. The problem of growth changes in the face and skull of anthropods and man. *Dental Cosmos.* 72:624—630, 1930.

Krogman, W. M. Growth of man. *Tab. Biol.*, 20:1—963, 1941.

Krogman, W. M. and Sassouni, V. *A syllabus in roentgengraphic cephalometry.* Philadelphia: Centre for Research in Child Growth.

Krogman, W. M. *A guide outline for the study of physical growth in children.*Philadelphia, 1958: Philadephia Centre for Research in Child Growth.

Krogman, W. M. *The growth of the head, face in American white and American negro boys and girls of Philadelphia, age* †— – × *years.* Philadephia: Philadelphia Centre for Research in Child Growth.

Lamont, H. Arrested thumbsucking; A longitudinal study. MSc. Thesis, University of Alberta, 1976.

Lande, M. J. Growth behavior of the human facial profile as revealed by serial cephalometric roentgenology. *Angle Orthod.*, 22:78, 1952.

Larsson, E. Dummy and finger-sucking habits with special attention to their significance for facial growth and occlusion, incidence study. *Swed. Dent. J.*, 64:667,1971.

Larsson, E. Dummy and finger-sucking habits with special attention to their significance for facial growth and occlusion. *Swed. Dent. J.*, 65:605—634, 1972.

Lavergne, J. and Gasson, N. A metal implant study of mandibular rotation. *Angle Orthod.*, 46: 144—150, 1977.

Levitas, T. C. Examine the habit and evaluate the treatment. *J. Dent. Child.*, 37:122—123, 161—164, 1970.

Lewis, A. B. and Roche, A. F. Cranial base elongation in boys during pubescence. *Angle Orthod.*, 44:83—93, 1974.

Levy, D. M. Thumb and finger sucking from the psychiatric angle. *Angle Orthod.*, 7:100—103, 1937.

Lu, K. H. Harmonic analysis of the human face. *Biometrics.* 21:491—505, 1965.

Mack, E. S. The dilemma in the management of thumbsucking. *J. Am. Dent. Assoc.*, 43:33—45, 1951.

Massler, M. and Wood, A. W. S. Thumbsucking. *J. Dent. Child.*, 16:1—9, 1949.

Meredith, H. V. and Higley, L. B. Relationships between dental arch widths of the face and head. *Am. J. Orthod.*, 37:193—204, 1951.

Meredith, H. V., Knott, V. B. and Hixon, E. H. Relation of the nasal and subnasal components of facial height in childhood. *Am. J. Orthod.,* 43:285—294, 1958.

Meredith, H. V. Recent studies on growth of the body and face. *Am. J. Orthod.,* 45:110—124, 1959.

Merow, W. W. A cephalometric statistical appraisal of dentofacial growth. *Angle Orthod.,*32:205—213, 1962.

Mershon, J. V. Possibilities and limitations in the treatment of closed bites. *Internat. J. Orthod.,* 23: 581—589, 1937.

Mills, J. R. E. The problem of overbite in Class II division 2 malocclusions. *Brit. J. Orthod.,* 1:34—48, 1973.

Moore, G. J. A longitudinal study of thumbsucking and open-bite in the Macaca mulatta. M.S.D. Thesis, University of Washington, 1970.

Moore, W. J. Association in the hominoid facial skeleton. *J. Anat.* 123:111—127, 1977.

Moss. M. L. and Young, R. W. A functional approach to craniology. *Am. J. Phys. Anthrop.,* 18: 281—292, 1960.

Moss, M. L. *The functional matrix in vistas in orthodontics.* Ed. B. Kraus and R. Reidel. Philadelphia: Lea & Febiger, 1962, 85—98.

Moss, M. L. Vertical growth of the human face. *Am. J. Orthod.,* 50:359—376, 1964.

Moss, M. L. The primacy of functional matrices in orofacial growth. *Dent. Pract.,* 19:65—73, 1968.

Moss, M. L. and Salentijn, L. The primacy role of functional matrices in facial growth. *Am. J. Orthod.,* 55:566—577, 1969.

Muller, G. Growth and development of the middle face. *J. Dent. Res.,* 42:385—399, 1961.

Nahoum, H. Vertical proportions and the palatal plane in anterior open-bite. *Am. J. Orthod.,* 59: 273—282, 1961.

Nahoum, H., Horowitz, S. L., Benedicto, E. A. Varieties of anterior open-bite. *Am. J. Orthod.,* 61: 486—492, 1972.

Nahoum, H. Anterior open-bite: a cephalometric analysis and suggested treatment procedure. *Am. J. Orthod.,* 67:513—521, 1975.

Nanda, R. L. The rates of growth of several facial components measured from serial cephalometric roentgenograms. *Am. J. Orthod.,* 41:658—673, 1955.

Opdebeeck, H., Bell, W. H., Eisenfeld, J. and Mishelevich, D. Comparative study between the SFS and LFS rotation as a possible morphogenic mechanism. *Am. J. Orthod.,* 74:509—521, 1978.

Ortiz, M. H. and Brodie, A. G. On the growth of the human head from birth to the third month of life. *Anat. Rec.,* 103:311—333, 1949.

Popovich, F. Cephalometric evaluation of vertical overbite in young adults. *J. Canad. Dent. Assoc.,* 21:209—222, 1955.

Popovich, F. The prevalence of sucking habit and its relationship to oral malformations. *Appl. Ther.,* 8:689—691, 1966.

Popovich, F. and Thompson, G. W. Thumb and finger sucking: Its relation to malocclusion. *Am. J. Orthod.,* 63:148—155, 1973.

Praskash, P. and Margolis, H. Dento cranio-facial relations in varying degrees of overbite. *Am. J. Orthod.,* 38:657—673, 1952.

Reidel, R. A. The relation of maxillary structures to cranium in malocclusion and in normal occlusion. *Angle Orthod.,* 22:142—145, 1952.

Richardson, A. Skeletal factors in anterior open-bite and deep overbite. *Am. J. Orthod.,* 56:114—127, 1969.

Ricketts, R. M. A study of changes in temporomandibular relations associated with treatment of Class II malocclusions. *Am. J. Orthod.,* 38:918—933, 1052.

Ricketts, R. M. Planning treatment on the basis of the facial pattern and an estimate of its growth. *Angle Orthod.,* 27:14—37, 1957.

Ricketts, R. M. The influence of orthodontic treatment on facial growth and development. *Angle Orthod.,* 27:14—37, 1957.

Ricketts, R. M. The influence of orthodontic treatment on facial growth and development. *Angle Orthod.,* 30:103—133, 1960.

Riolo, M. L., Moyers, R. E., McNamara, J. A. and Hunter, W. S. *An Atlas of Craniofacial Growth,* Ann Arbor, Centre of Human Growth and Development, University of Michigan, 1974.

Ruttle, A. T. Quigley, W., Crouch, J. T., and Evans, G. E. A serial study of the effects of finger-sucking. *J. Dent. Res.,* 32:739, 1953.

Sarnas, K. V. Inter- and intra-family variations in the facial profile; an X-ray cephalometric investigation on young adult male sibs. *Odont. Revy.,* 10: Supp. 4, pp. 3—116, 1959.

Sassouni, V. A roentgenographic cephalometric analysis of cephalo-facio-dental relationships. *Am. J. Orthod.,* 41:234—264, 1955.

Sassouni, V. and Nanda, S. Analysis of dentofacial vertical proportions. *Am. J. Orthod.,* 50:801—823, 1964.

Sassouni, V. A classification of skeletal facial types. *Am. J. Orthod.,* 55:109—123, 1969.

Sassouni, V. *Orthodontics in dental practice.* St. Louis: C. V. Mosby Co., 1971.

Schendel, S. A. Eisenfeld, J., Bell, W. H., Epker, B. N. and Mishelevich, D. J. The long facce syndrome: vertical maxillary excess. *Am. J. Orthod.,* 70:398—408, 1976.

Schudy, F. F. Cant of the occlusal plane and axial inclinations of teeth. *Angle Orthod.,* 33:69—82, 1963.

Schudy, F. F. Vertical growth versus anteroposterior growth as related to function and treatment. *Angle Orthod.,* 34:75—93, 1964.

Schudy, F. F. The rotation of the mandible resulting from growth; Its implication of orthodontic treatment. *Angle Orthod.,* 35:36—50, 1965.

Schudy, F. F. The control of vertical overbite in clinical orthodontics. *Angle Orthod.,* 38:19—39, 1968.

Scott, J. The doctrine of functional matrices. *Am. J. Orthod.,* 56:38—44, 1969.

Sillman, J. H. Thumbsucking and the dentition: a serial study. *N.Y. State Dent. J.,* 17:493—502, 1951.

Silverstein, A. Changes in the bony facial profile coincident with treatment of Class II division I (Angle) malocclusion. *Angle Orthod.,* 24:214, 1954.

Smeets, H. J. L. A roentgenocephalometric study of the skeletal morphology of Class II division II malocclusion in adult cases. *Europ. Orthod. Soc. Trans.,* 247—259, 1962.

Spatz, C. and Johnston, J. O. *Basic Statistics: Tables of Distributions.* R. E. Kich, ed. Monterey, California: Brooks/Cole Publishing Company, 1976.

Steadman, S. Predetermining the overbite and overjet. *Am. J. Orthod.,* 19:101—105, 1949.

Steiner, C. Cephalometrics for you and me. *Am. J. Orthod.,* 39:729—755, 1953.

Strang, R. H. W. and Thompson, W. M. *A Textbook of Orthodontia.* Ed. 4. Philadelphia: Lea and Febiger, 1958.

Swindler, D. R. and Sassouni, V. Open bite and thumbsucking in rhesus monkeys. *Angle Orthod.,* 32:27—36, 1962.

Swinehart, E. W. Relation of thumbsucking to malocclusion. *Am. J. Orthod.,* 24:509—521, 1938.

Subtelny, J. D. and Sakuda, M. Open-bite: diagnosis and treatment. *Am. J. Orthod.,* 50:337—358, 1964.

Taft, L. L. A diagnostic study of the dentition. Dentofacial pattern and cranial base of prolonged thumbsuckers. *Am. J. Orthod.,* 52:703—705, (abst.,), 1966.

Thompson, J. R. and Brodie, A. G. Factors in the position of the mandible. *J. Am. Dent. Assoc.,* 29:925—941, 1942.

Todd, T. W. Prognathism; a study in development of the face. *J. Am. Dent. Assoc.,* 19:2172—2184, 1932.

Traisman, A. S. and Traisman, H. S. Thumb and finger sucking; a study of 2,650 infants and children. *J. Pediat.,* 52:566—572, 1958.

Weinberg, H. and Kronman, J. H. Orthodontic influence upon anterior face height. *Angle Orthod.,* 36:80—88, 1966.

Wylie, W. L. A quantitative method of comparison of craniofacial patterns in different individuals; its application to a study of parents and offspring. *Am. J. Anat.,* 74:39—60, 1944.

Wylie, W. L. The relationship between ramus height, dental h eight and overbite. *Am. J. Orthod.,* 32:57—67, 1946.

Wylie, W. L. An assessment of anteroposterior dysplasia. *Angle Orthod.,* 17:97—109, 1947.

Wylie, W. L. and Johnson, E. L. Rapid evaluation of facial hypoplasia in the vertical plane. *Angle Orthod.,* 22:165—182, 1952.

Zadik, D., Stern, N. and Litner, M. Thumb- and pacifier-sucking habits. *Am. J. Orthod.,*, 71:197—201, 1977.

CHAPTER 8

APPENDIX

Utilization of Appendix

Each of the linear skeletal and dentoalveolar variables that were used in the present study have been derived from *An Atlas of Craniofacial Growth* by Riolo *et al.* (1974). Each page contains several components which are described for each figure.

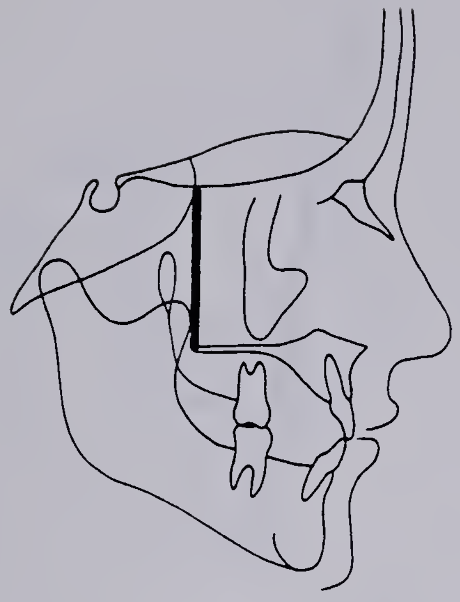
(a) An identification block appears in the upper right corner. It contains a complete designation of the measurement (e.g., Nasion–Anterior Nasal Spine), and its abbreviation (N–ANS).

(b) A drawing in the upper left corner illustrates diagramatically where the measurement is made.

(c) Tabulated data is given for each sex. The quantities tabulated are the age of measurement (i.e., six to sixteen years), the sample size at each age, the estimated mean value at each age, and the estimated standard deviation.

(d) A column of asterisks (*) may appear between the male and female tabulations. The presence of a single asterisk on the line for a particular age indicates that a two-sample t-test comparing the male and female samples was significant at the 0.05 level of significance. Two asterisks indicate that it was significant at the 0.02 level. In the figure, significant sexual dimorphism can be found at ages thirteen–sixteen. Some measurements show no sexual dimorphism so consequently no asterisks appear.

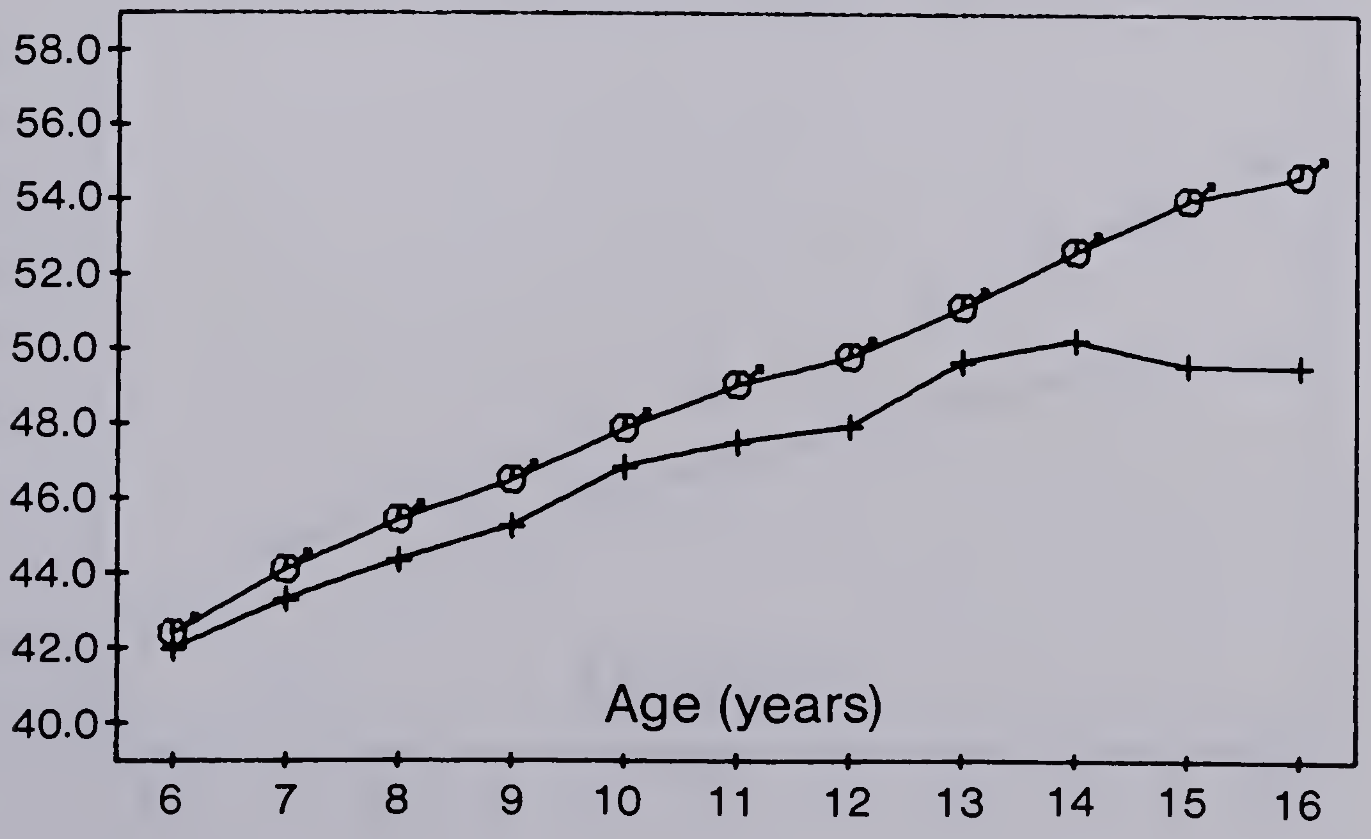
(e) The graph at the bottom of the page shows the male and female mean values plotted against age. The plot characters for each sex are different. The scale on the vertical axis has been chosen separately for each variable with increments of 0.5, 1, 2, or 5 units.

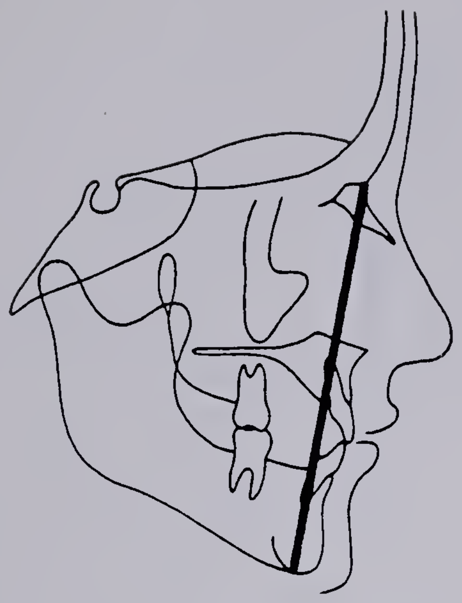


Ethmoid Registration Point –
Anterior nasal spine –
Posterior nasal spine

SE– ANS–PNS

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	42.4	2.8		6	24	42.0	2.6
7	44	44.1	2.9		7	31	43.3	2.8
8	44	45.5	2.9		8	36	44.4	2.8
9	47	46.5	2.7		9	31	45.3	3.0
10	46	47.9	3.0		10	35	46.9	3.4
11	43	49.1	3.4		11	30	47.5	3.3
12	44	49.8	3.7	*	12	27	48.0	3.0
13	43	51.2	3.5		13	29	49.7	2.6
14	39	52.7	3.5	**	14	25	50.3	2.4
15	33	54.0	3.8	**	15	19	49.6	2.8
16	23	54.7	4.4	**	16	9	49.6	3.3

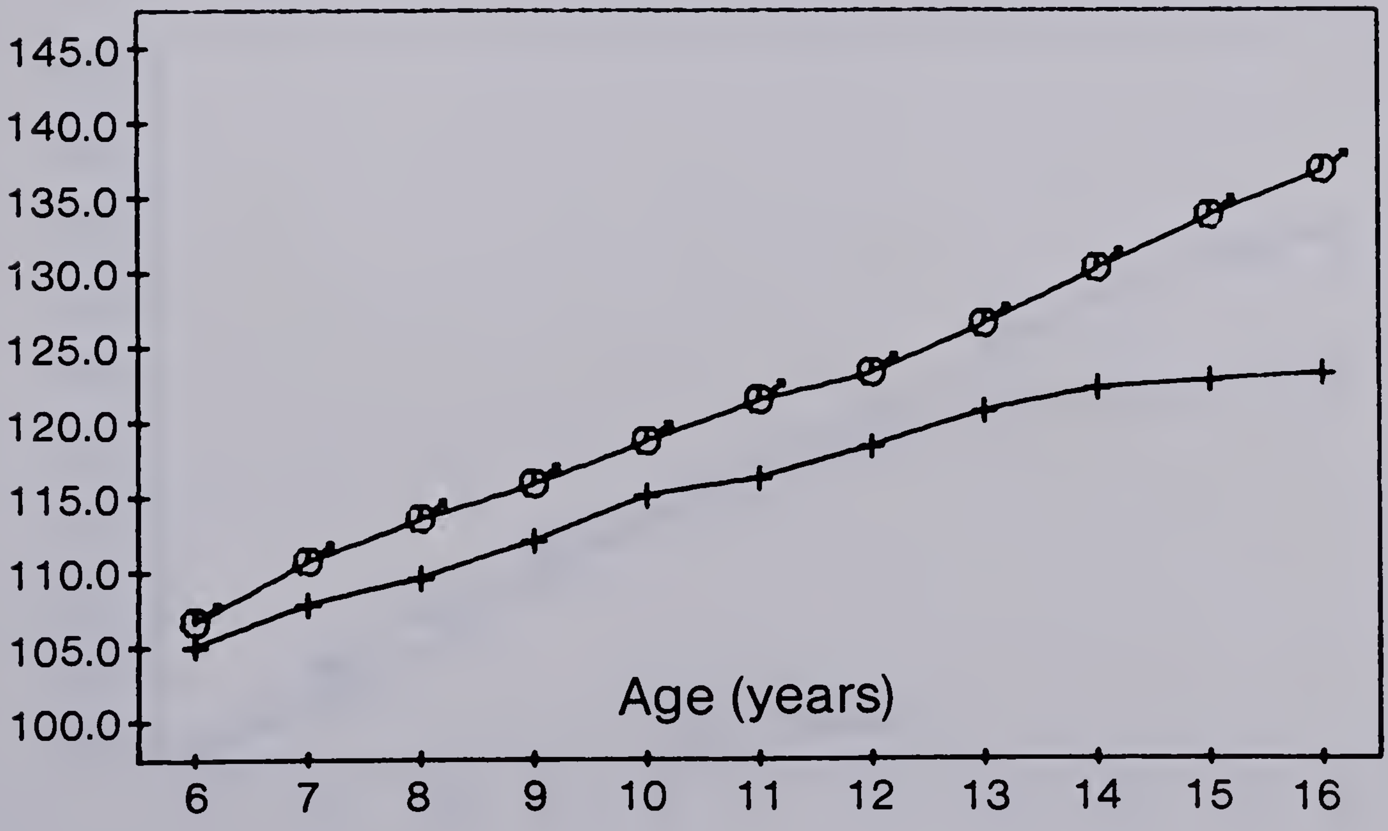


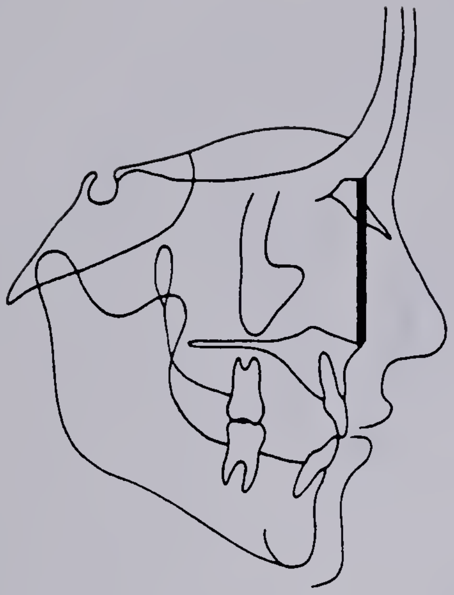


Menton—Nasion

ME—N

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	106.7	5.2		6	25	105.0	5.1
7	44	110.7	5.8	*	7	31	107.8	5.3
8	44	113.6	5.6	**	8	36	109.5	5.4
9	46	115.9	5.4	**	9	31	112.1	5.7
10	45	118.7	5.7	**	10	35	115.1	6.7
11	43	121.5	6.0	**	11	30	116.2	6.4
12	44	123.3	6.3	**	12	27	118.3	6.0
13	42	126.6	7.0	**	13	29	120.7	5.8
14	39	130.3	7.9	**	14	25	122.3	5.9
15	32	133.8	7.8	**	15	19	122.7	6.4
16	23	136.8	7.9	**	16	9	123.2	5.1

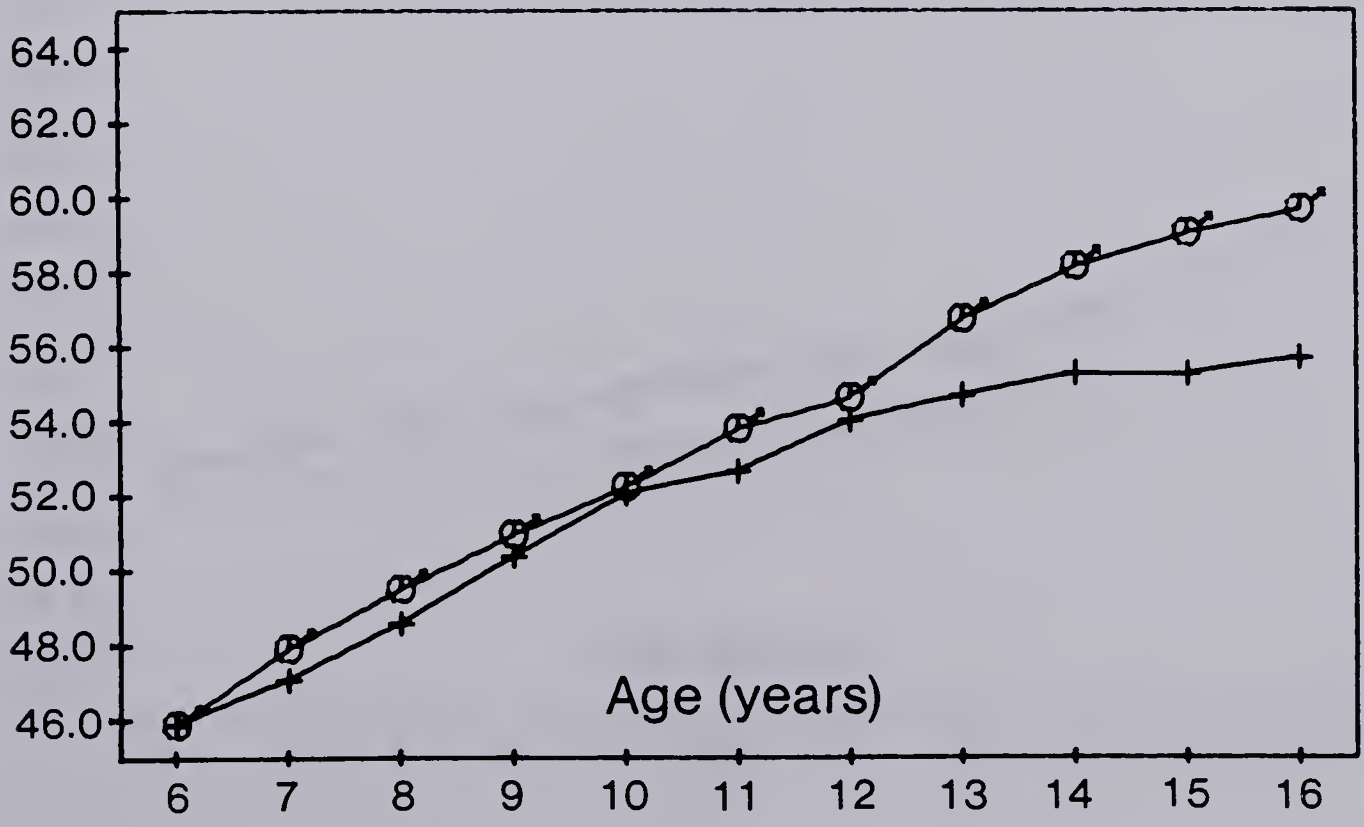


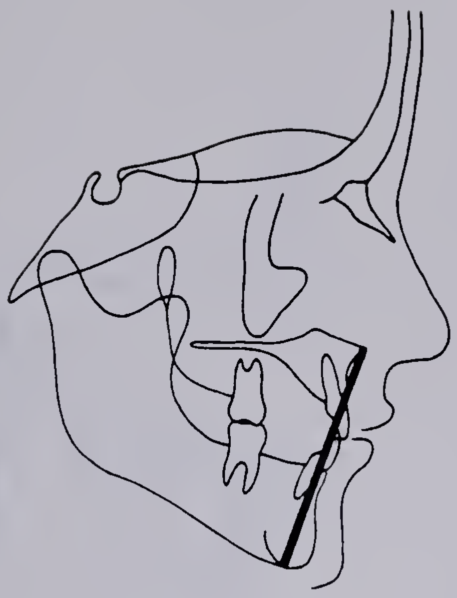


Nasion—Anterior nasal spine

N—ANS

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	45.9	2.		6	25	45.9	3.1
7	44	47.9	3.2		7	31	47.1	2.9
8	44	49.5	2.8		8	36	48.6	3.0
9	47	51.0	3.0		9	31	50.4	3.1
10	46	52.3	3.1		10	35	52.1	3.7
11	43	53.8	3.4		11	30	52.7	3.3
12	44	54.6	3.6		12	27	54.0	3.7
13	43	56.8	3.7	**	13	29	54.7	3.3
14	40	58.2	4.1	**	14	25	55.3	2.7
15	33	59.0	4.0	**	15	19	55.3	3.2
16	23	59.7	3.9	**	16	9	55.7	2.1



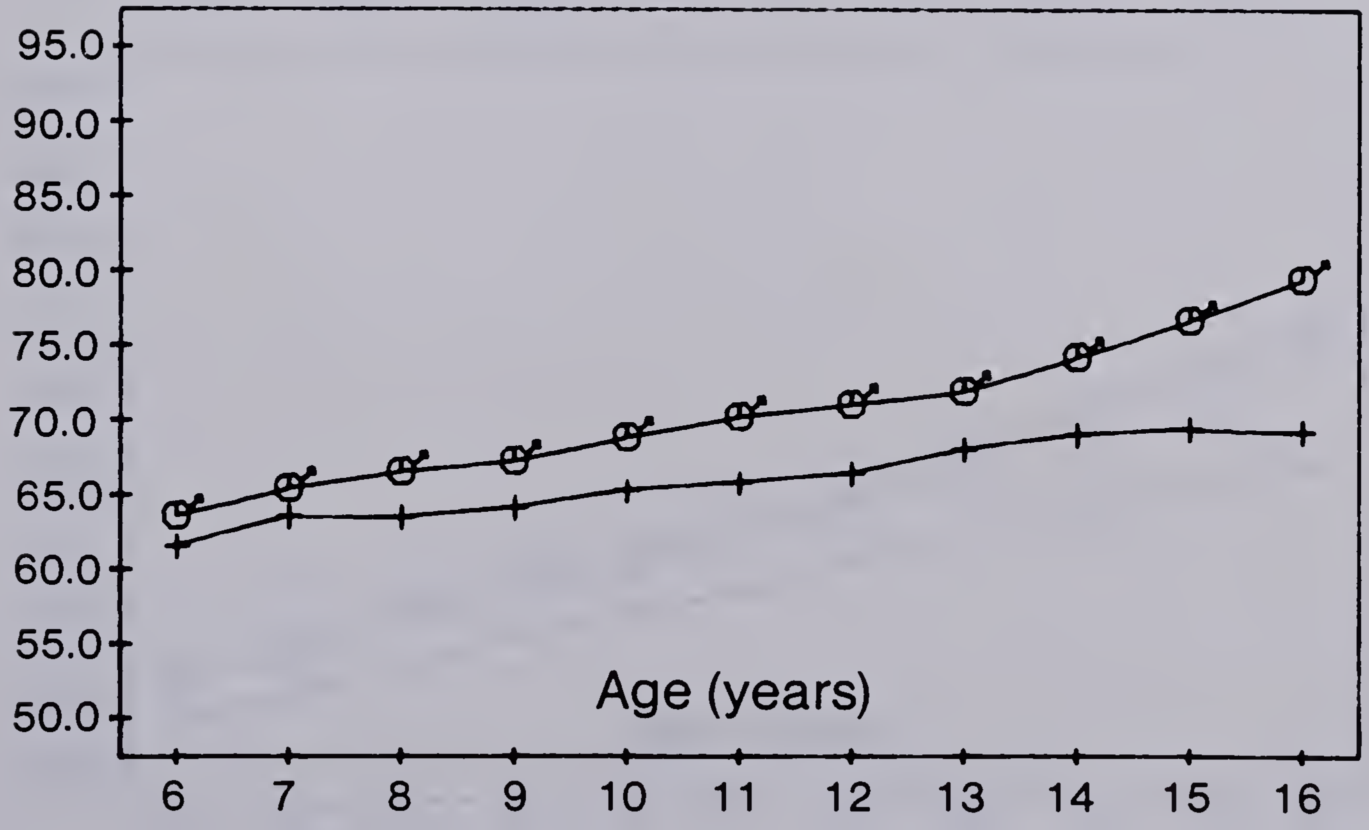


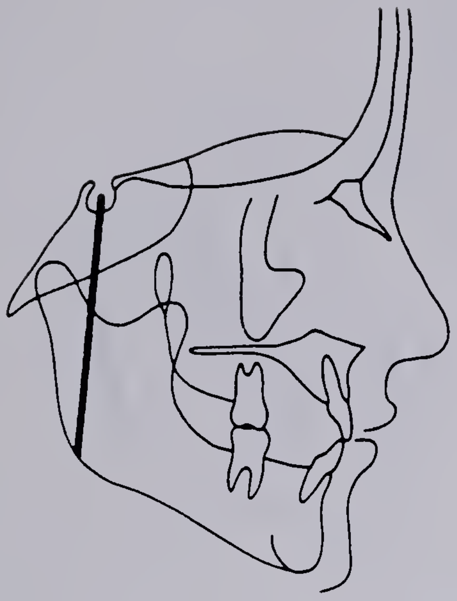
Anterior Nasal Spine–Menton

ANS – ME

Age	N	Male Mean mm	S.D. mm
6	37	63.7	4.0
7	44	65.5	4.4
8	44	66.6	4.4
9	46	67.3	4.3
10	45	68.9	4.9
11	43	70.3	4.8
12	44	71.1	5.1
13	42	72.0	5.6
14	39	74.3	5.8
15	32	76.7	6.4
16	23	79.5	6.2

Age	N	Female Mean mm	S.D. mm
6	25	61.6	3.9
7	31	63.6	4.1
8	36	63.5	4.2
9	31	64.1	4.6
10	35	65.3	4.9
11	30	65.8	4.6
12	27	66.5	3.8
13	29	68.1	4.5
14	25	69.1	5.0
15	19	69.5	5.3
16	9	69.3	5.2

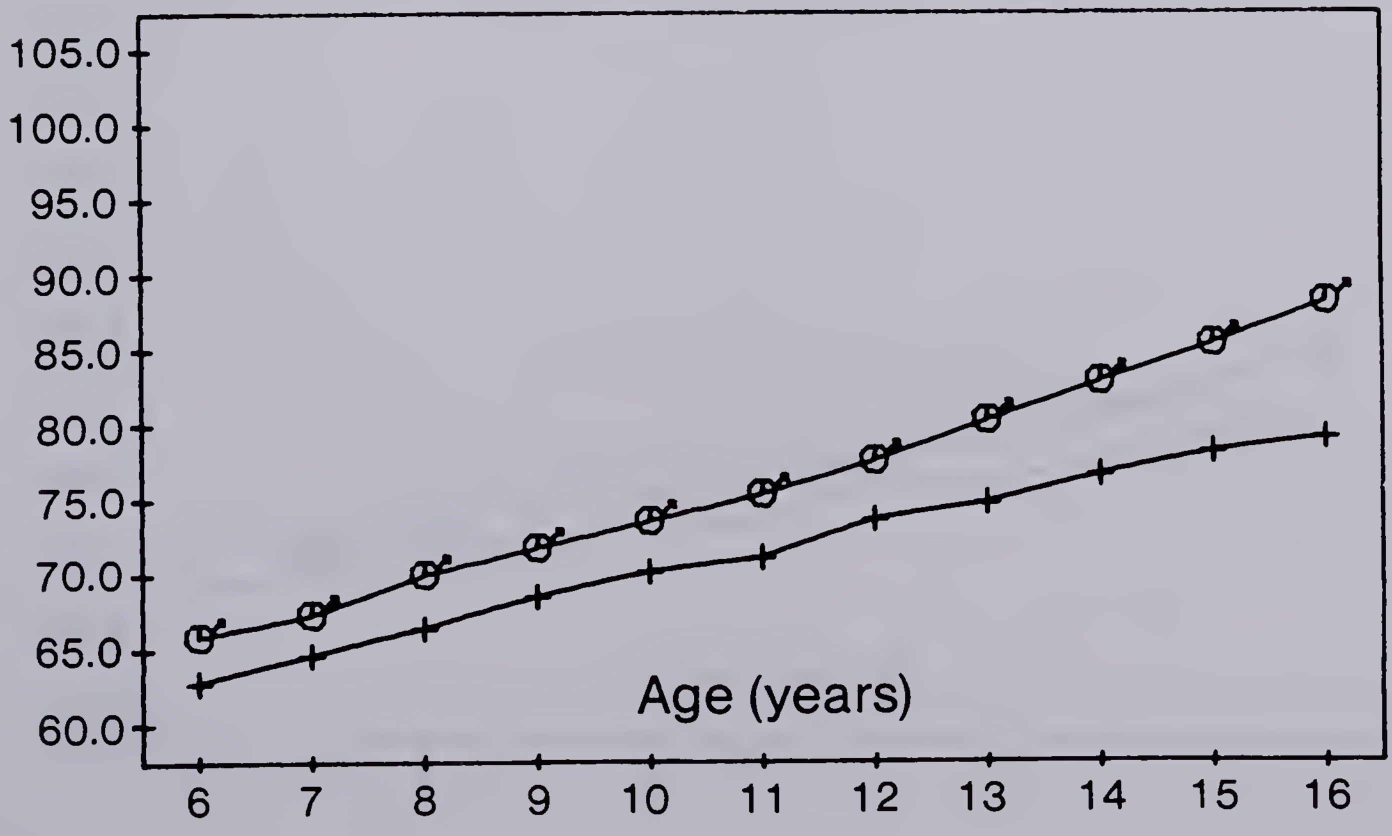


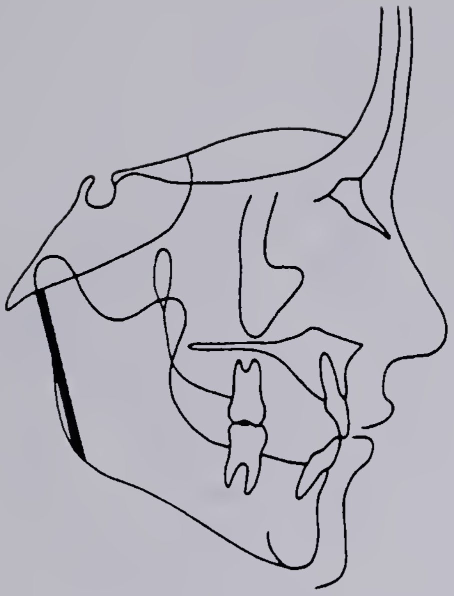


Sella – Gonion

S–GO

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	65.9	4.7	**	6	25	62.8	4.3
7	44	67.4	4.6	**	7	31	64.6	4.4
8	44	70.0	4.3	**	8	36	66.4	4.0
9	46	71.9	4.4	**	9	31	68.5	4.4
10	45	73.6	4.6	**	10	35	70.2	4.1
11	43	75.4	4.9	**	11	30	71.1	4.4
12	44	77.6	5.3	**	12	27	73.7	5.1
13	43	80.3	6.1	**	13	29	74.8	4.4
14	40	82.9	5.6	**	14	25	76.6	5.5
15	33	85.4	5.6	**	15	19	78.2	5.1
16	23	88.2	5.9	**	16	9	79.1	4.3

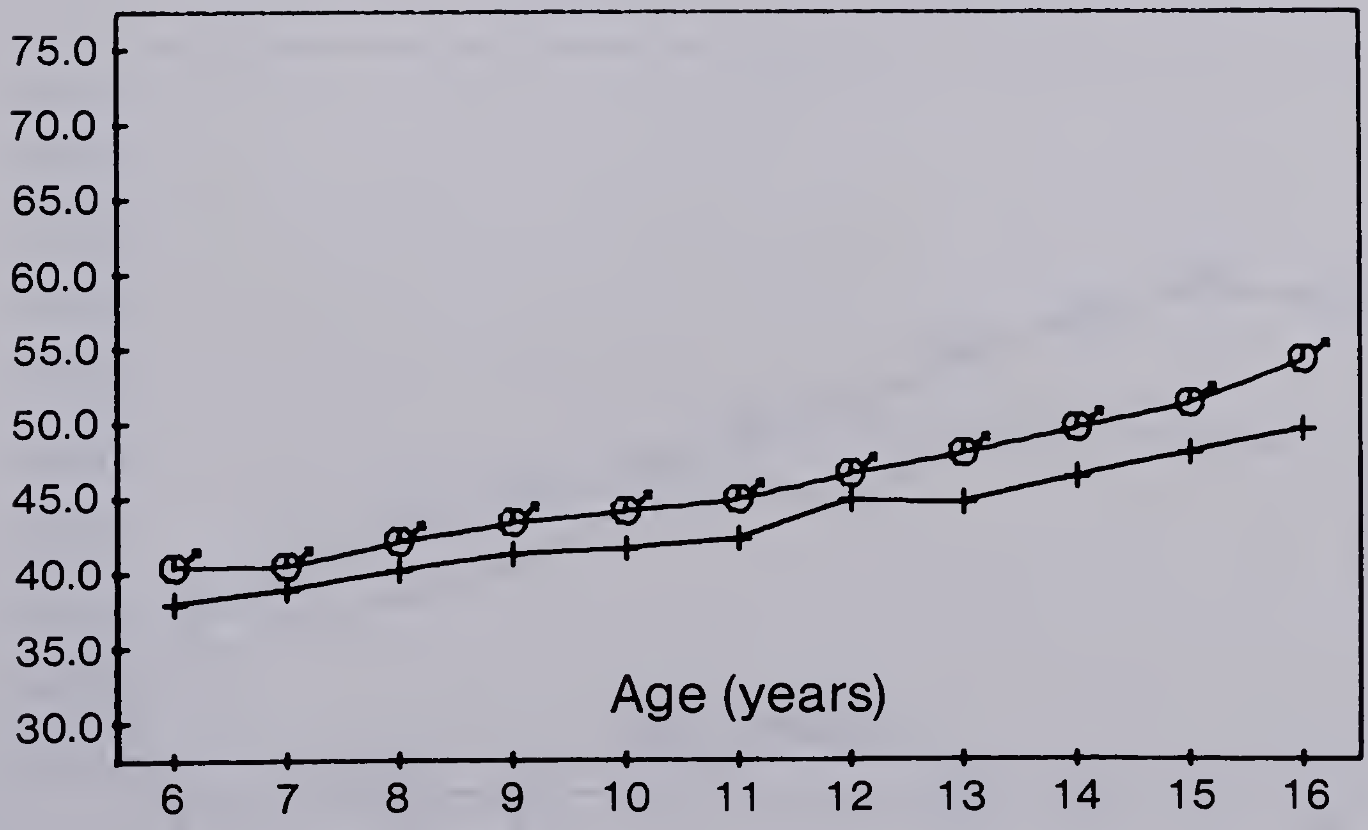


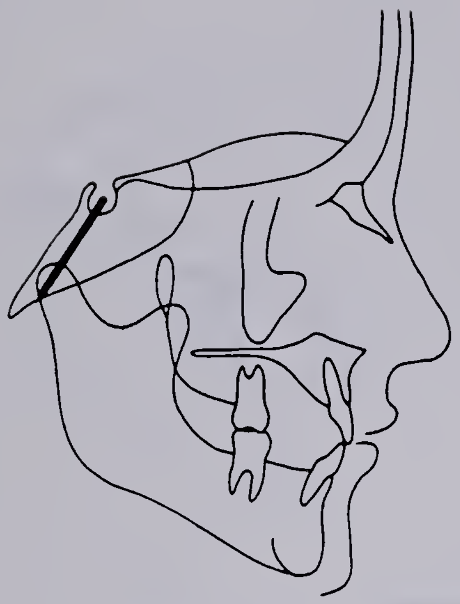


Articulare – Gonion

AR – GO

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	40.4	3.3	**	6	25	37.9	3.7
7	44	40.5	3.3	**	7	31	38.9	3.4
8	44	42.2	3.4	**	8	36	40.2	3.2
9	47	43.4	3.3	**	9	31	41.2	3.5
10	46	44.2	3.4	**	10	35	41.6	3.2
11	43	45.0	3.9	**	11	30	42.3	3.1
12	44	46.7	3.8		12	27	44.9	3.9
13	43	48.0	4.6	**	13	29	44.7	3.8
14	40	49.8	4.6	**	14	25	46.4	4.6
15	33	51.4	4.6	**	15	19	48.1	4.1
16	23	54.3	4.1	**	16	9	49.6	3.9

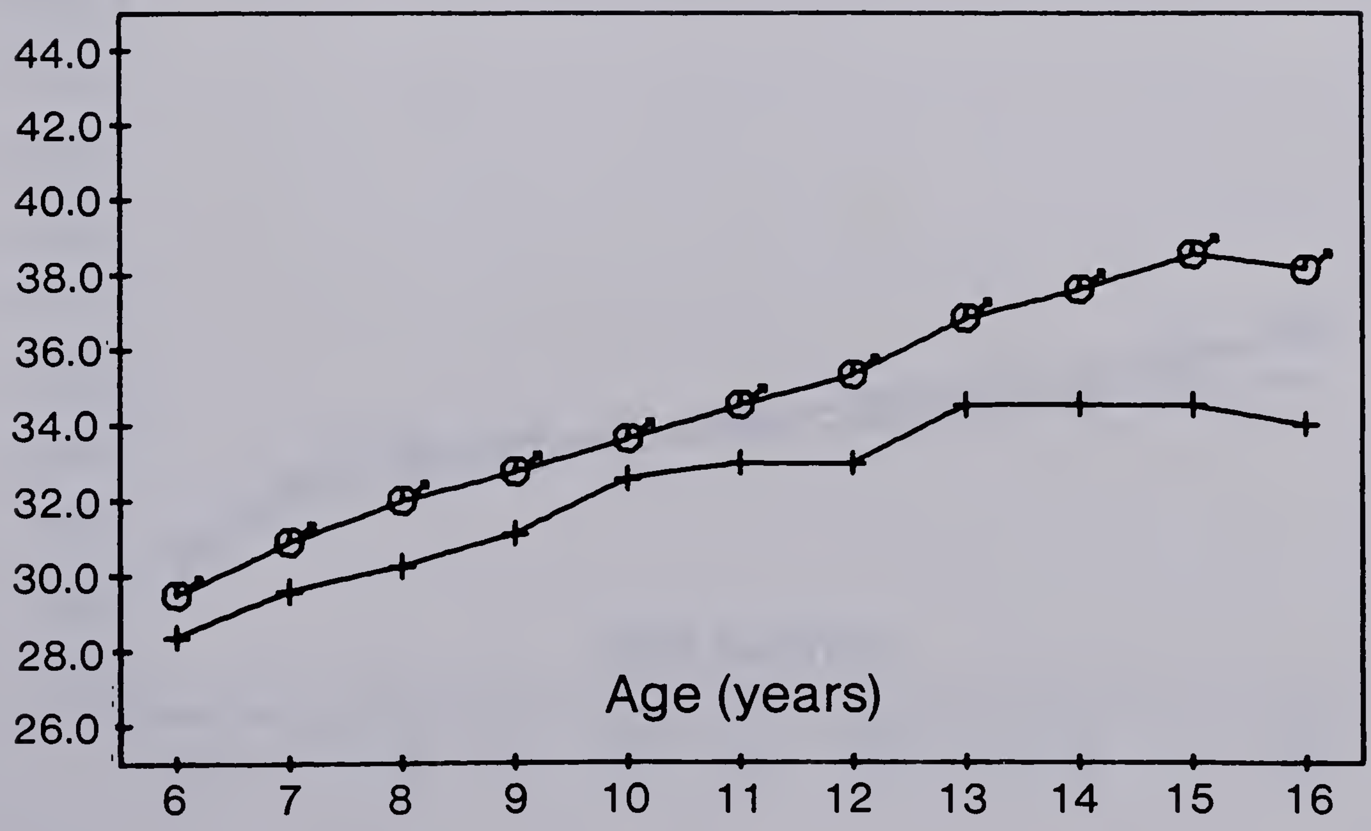


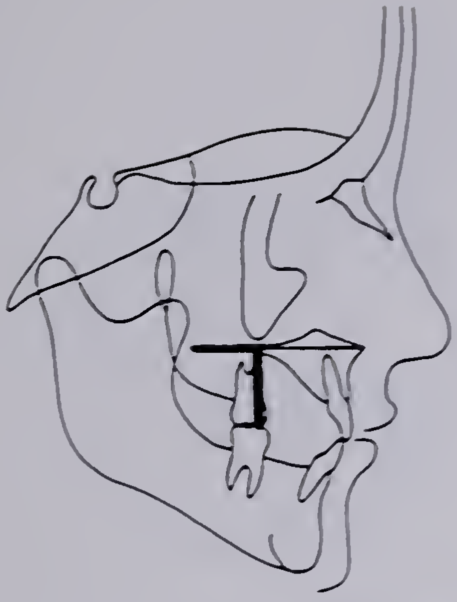


Sella – Articulare

S – AR

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	29.5	2.8		6	25	28.4	3.1
7	44	30.9	2.8		7	31	29.6	3.1
8	44	32.0	3.0	**	8	36	30.2	3.4
9	46	32.8	2.6	**	9	31	31.1	3.2
10	45	33.7	3.1		10	35	32.6	3.4
11	43	34.6	3.0	*	11	30	33.0	3.7
12	44	35.4	3.3	**	12	27	33.0	3.4
13	43	36.9	3.5	**	13	29	34.6	3.8
14	40	37.6	3.3	**	14	25	34.6	3.7
15	33	38.6	3.4	**	15	19	34.6	4.0
16	23	38.2	3.1	**	16	9	34.0	2.9

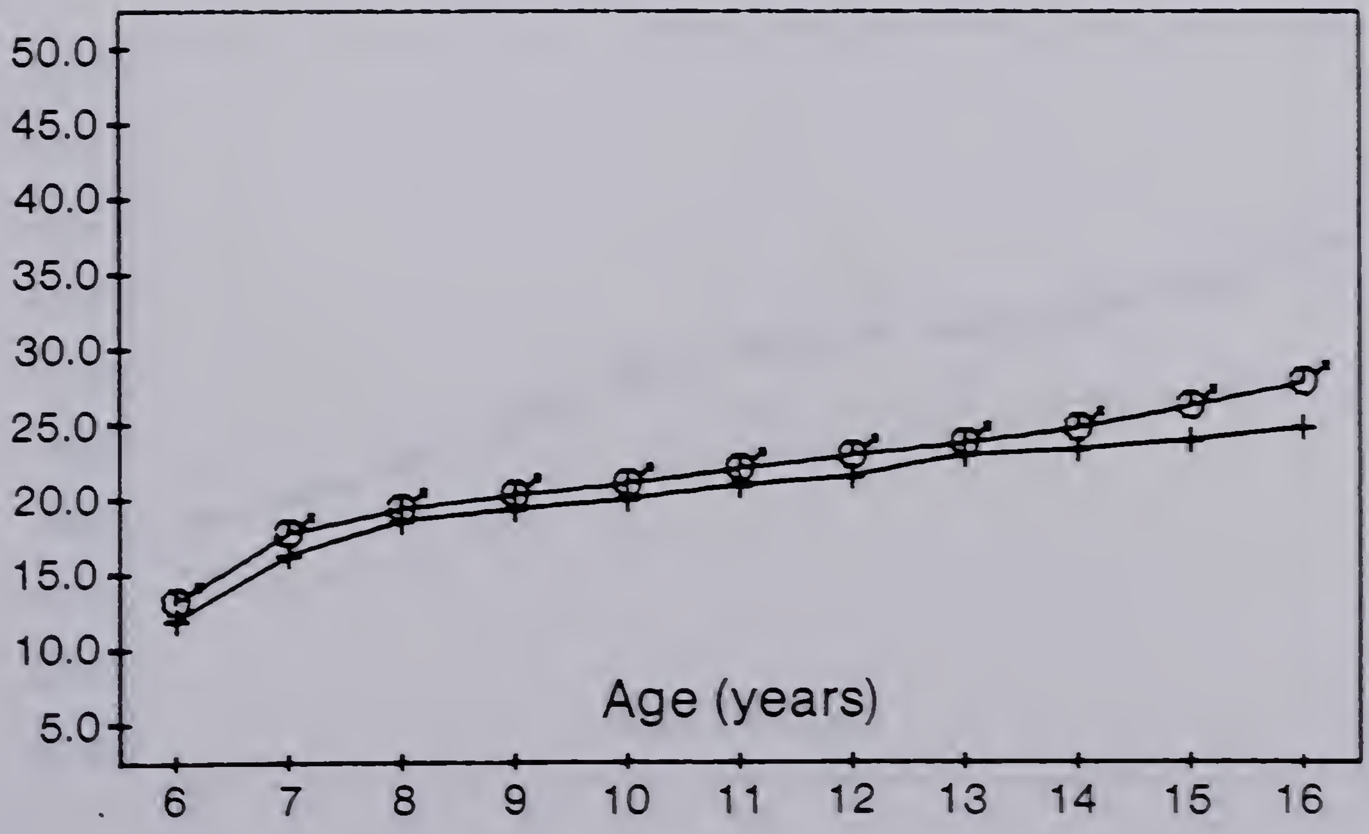


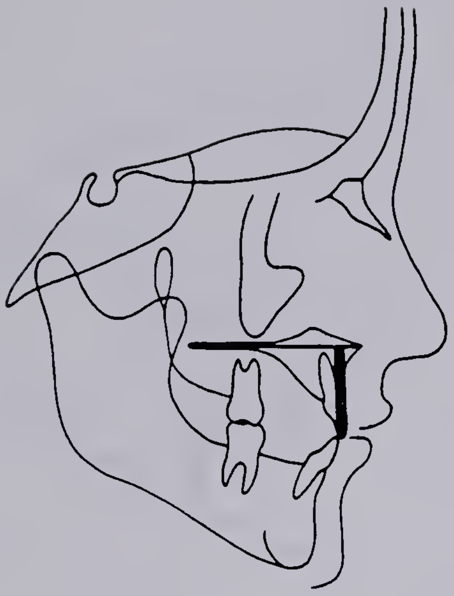


Upper Molar Mesial Cusp Tip
perpendicular to
Palatal Plane

UM ⊥ ANS–PNS

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	22	13.2	3.9		6	17	11.9	3.5
7	40	17.8	2.5	**	7	26	16.3	2.7
8	43	19.5	1.8	*	8	35	18.5	2.1
9	47	20.4	2.2	*	9	31	19.3	1.9
10	46	21.1	2.4	*	10	35	20.0	2.1
11	43	22.1	2.3	*	11	30	20.9	1.9
12	44	23.0	2.1	**	12	27	21.5	1.8
13	42	23.8	2.4		13	29	22.9	2.3
14	38	24.8	2.6	**	14	25	23.3	2.0
15	30	26.3	3.0	**	15	19	23.9	2.2
16	22	27.9	3.1	**	16	9	24.8	2.2

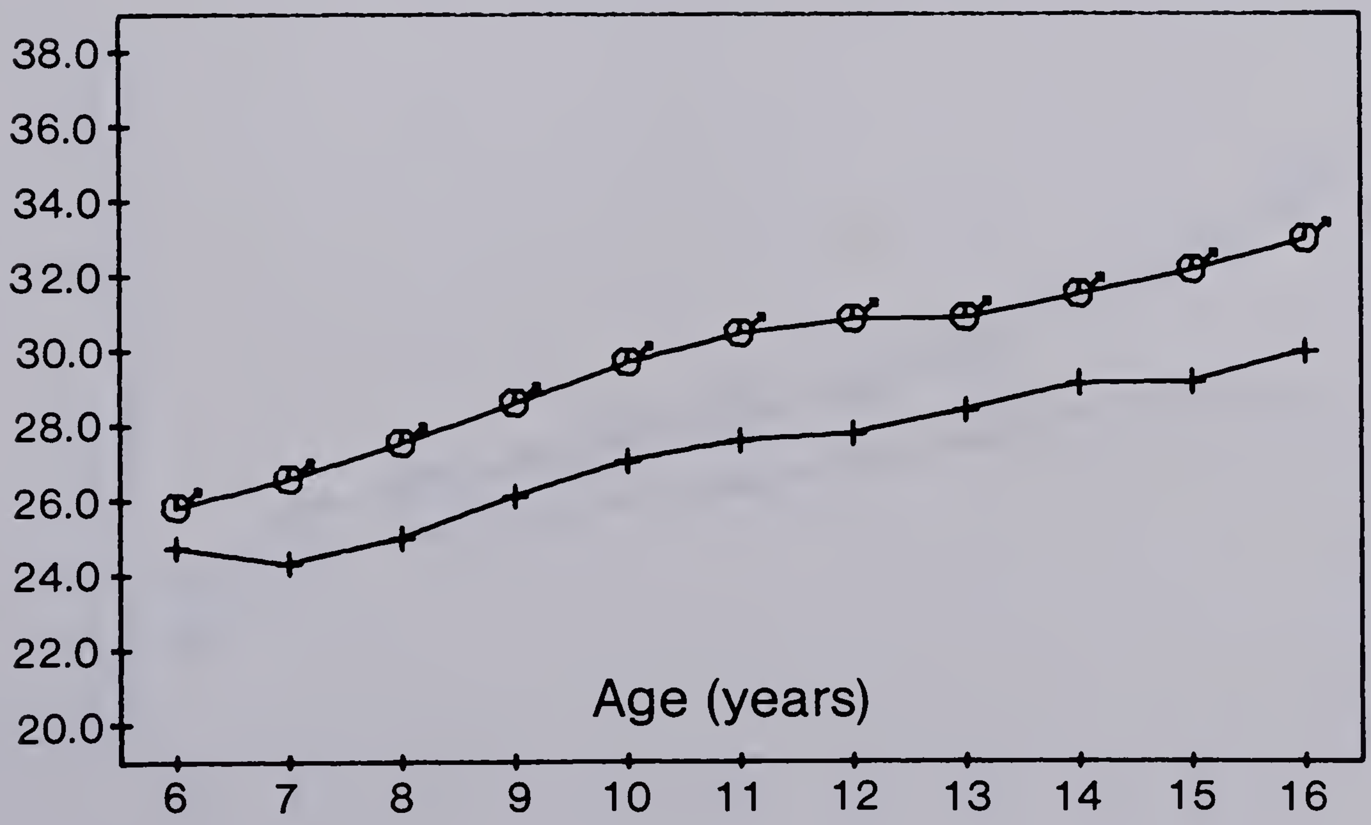


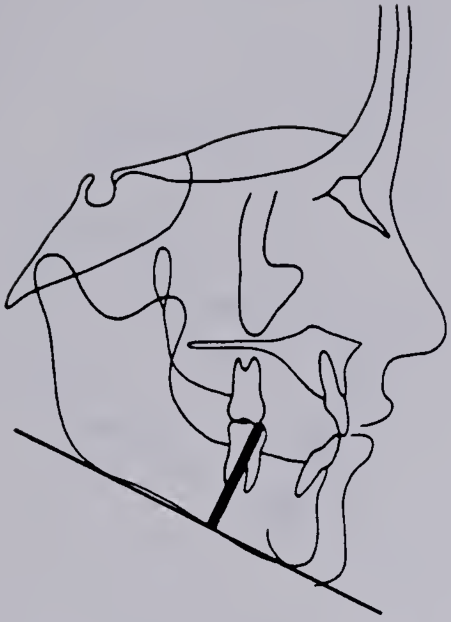


Upper Incisor Incisal Edge perpendicular to Palatal Plane

UI $\underline{1}$ ANS–PNS

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	25.8	2.3		6	24	24.7	2.1
7	44	26.6	2.4	**	7	31	24.3	3.3
8	44	27.5	2.3	**	8	36	25.0	2.8
9	47	28.6	2.5	**	9	31	26.1	2.6
10	46	29.7	2.2	**	10	35	27.0	2.8
11	43	30.5	2.0	**	11	30	27.6	2.7
12	44	30.9	2.2	**	12	27	27.8	2.7
13	43	30.9	2.4	**	13	29	28.4	2.6
14	39	31.5	2.3	**	14	25	29.1	3.0
15	33	32.2	2.8	**	15	19	29.1	3.3
16	23	33.0	3.2	**	16	9	30.0	2.9

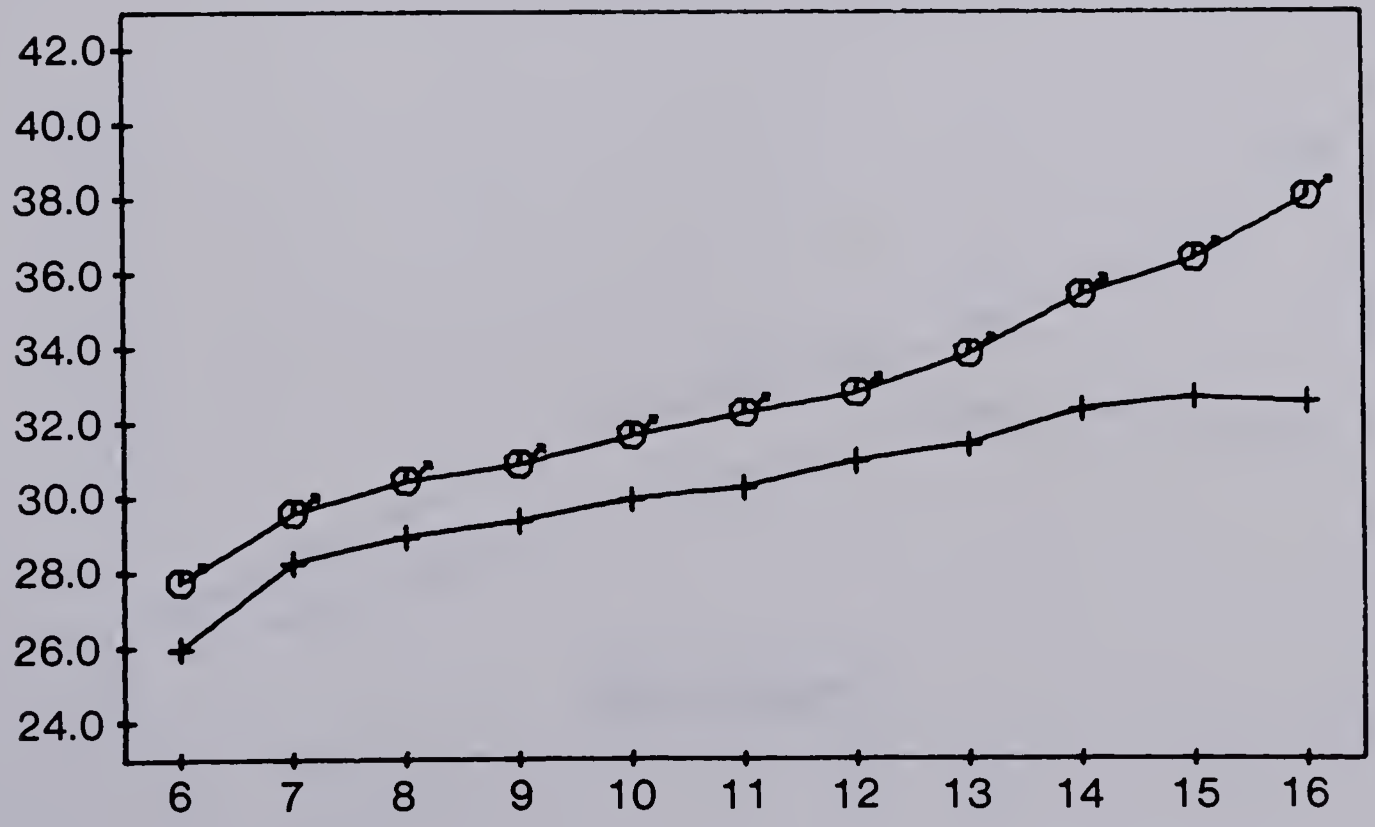


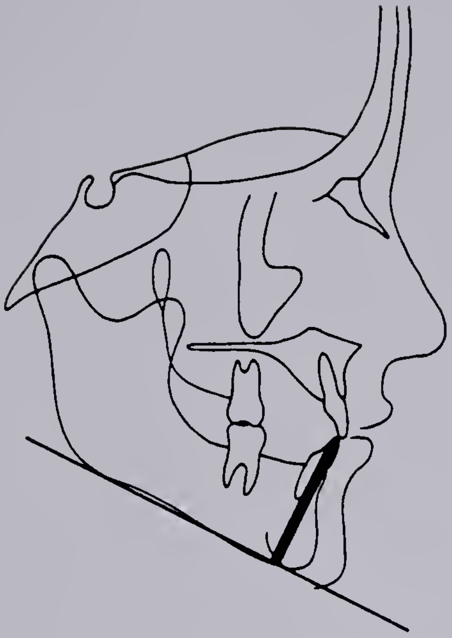


Lower Molar Mesial Cusp Tip
perpendicular to
Mandibular Plane

LM $\underline{1}$ GO–ME

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	27.7	4.0		6	25	26.0	3.9
7	44	29.6	2.2	**	7	31	28.2	2.7
8	44	30.5	2.1	**	8	36	28.9	1.5
9	47	30.9	2.0	**	9	31	29.4	2.1
10	46	31.7	1.9	**	10	35	29.9	2.2
11	43	32.3	2.2	**	11	30	30.3	1.9
12	44	32.8	2.5	**	12	27	31.0	2.2
13	42	33.8	3.0	**	13	29	31.4	2.2
14	39	35.4	3.0	**	14	25	32.3	2.4
15	32	36.4	3.0	**	15	19	32.7	2.9
16	23	38.0	2.8	**	16	9	32.6	2.9

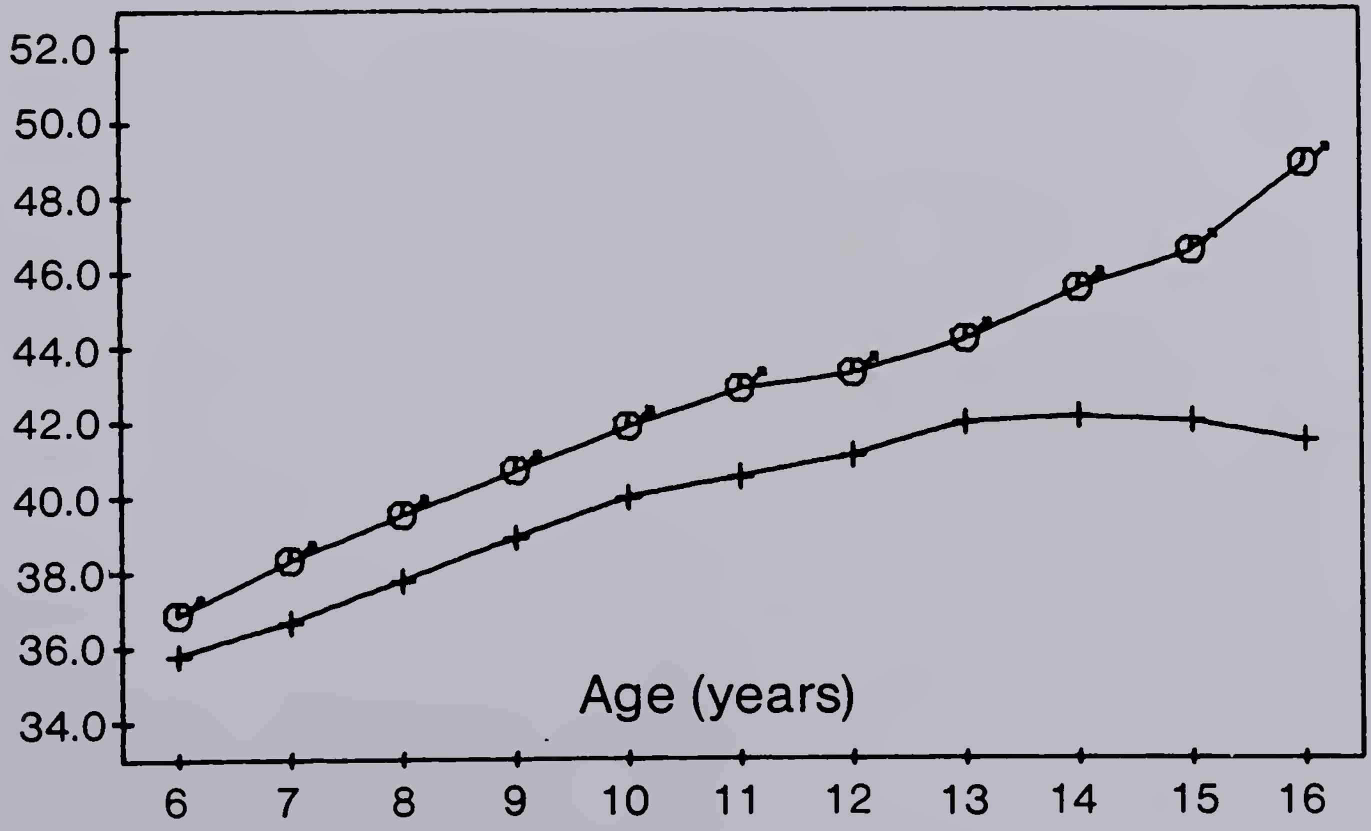




Lower Incisor Incisal Edge
perpendicular to
Mandibular Plane

LI $\underline{1}$ GO–ME

Age	N	Male Mean mm	S.D. mm		Age	N	Female Mean mm	S.D. mm
6	37	36.9	2.6		6	25	35.8	2.3
7	44	38,3	2.5	**	7	31	36.7	2.2
8	44	39.6	2.4	**	8	36	37.8	2.2
9	47	40.7	2.4	**	9	31	38.9	2.5
10	46	41.9	2.4	**	10	35	40.0	2.6
11	43	42.9	2.7	**	11	30	40.5	2.6
12	44	43.3	2.7	**	12	27	41.1	2.2
13	42	44.2	3.1	**	13	29	42.0	2.6
14	39	45.6	3.6	**	14	25	42.1	2.6
15	32	46.6	3.4	**	15	19	42.0	3.2
16	23	48.9	3.0	**	16	9	41.5	3.1



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